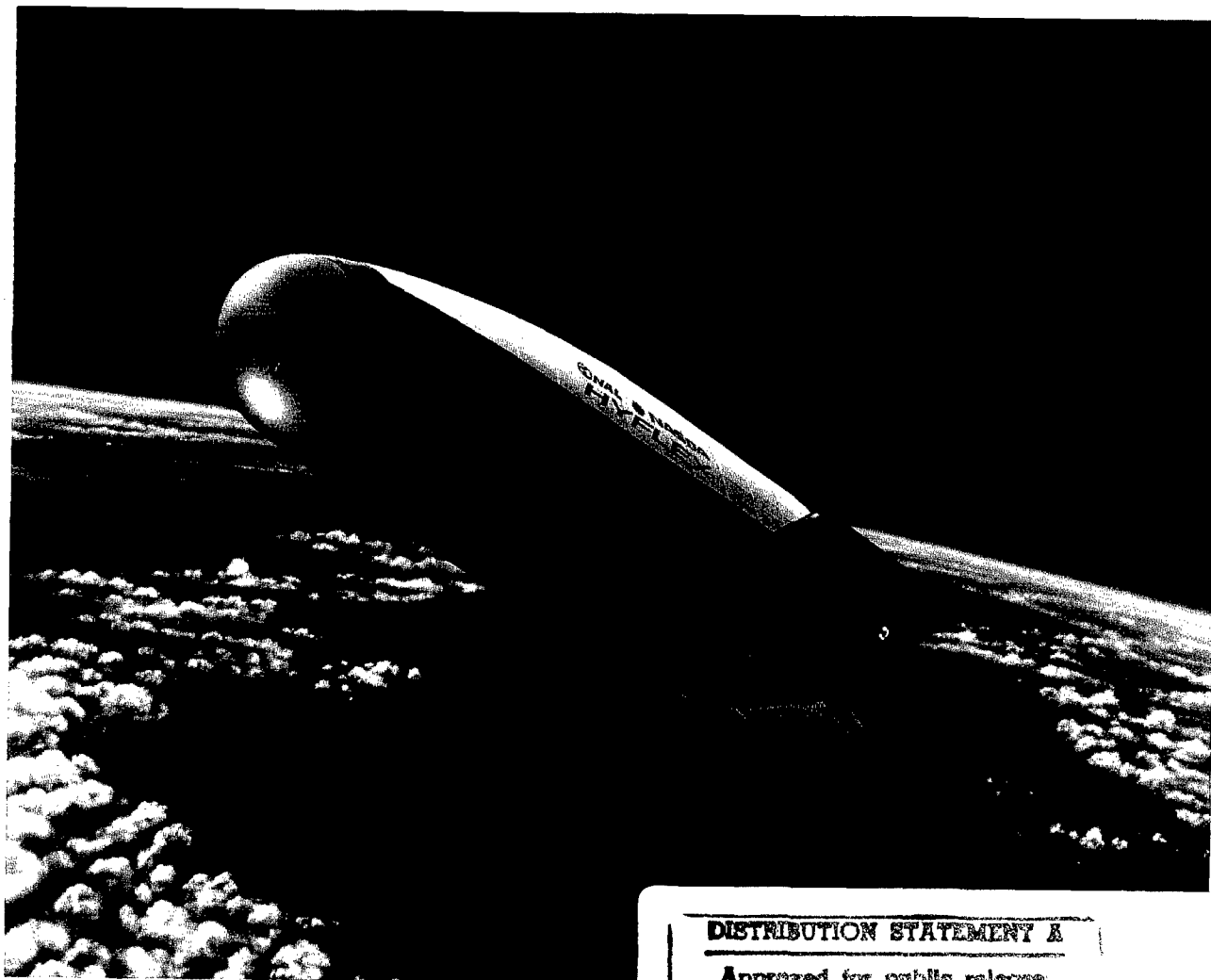


# Europe & Asia in Space



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Front Cover: The Japanese Hypersonics Flight Experiment (HYFLEX) will be the first mission of the new J-I launch vehicle and will be instrumental in assessing reentry technology for the planned H-II Orbiting Plane (HOPE).

Back Cover: The Russian RD-701 tri-propellant (liquid oxygen, liquid hydrogen, and kerosene) engine is being considered for the Multi-purpose Aerospace System (MAKS), an air-launched, unmanned reusable spaceplane.



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Abstract: This second edition of "Europe and Asia in Space" covers the space activities of European and Asian countries during 1993-1994. Ballistic missile proliferation in third world countries and advances in IR technology detectors have generated increased interest of France, Western European Union and Japan in space based early warning systems.

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# **EUROPE AND ASIA IN SPACE**

## **1993-1994**

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**Nicholas L. Johnson**  
Principal Scientist

**David M. Rodvold**  
Associate Senior Scientist

Prepared for  
**USAF Phillips Laboratory**  
Kirtland AFB, NM 87117

Prepared by  
**Kaman Sciences Corporation**  
1500 Garden of the Gods Road  
Colorado Springs, Colorado 80907

**The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the US Government.**

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## FOREWORD



The United States Air Force's Phillips Laboratory is proud to present this second edition of *Europe and Asia in Space* covering the space activities of European and Asian countries during 1993-1994. The success of *Europe and Asia in Space* can be, in part, measured by the distribution of the 1991-1992 book. To date over 2200 copies have been mailed. Requests have been from around the world and include individuals, corporations, educational institutions, and governments. Feedback has been universally positive. We hope you find *Europe and Asia in Space* useful and informative. We would like to hear your comments on this report. Please phone (505)-846-1761 or send comments to:

Phillips Laboratory/XPF  
Attn: Europe and Asia in Space Project  
3550 Aberdeen Ave SE  
Kirtland AFB, NM 87117-5776

A handwritten signature in black ink, which appears to read "Michael L. Heil".

MICHAEL L. HEIL, Colonel, USAF  
Commander



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## PRINCIPAL ACRONYMS

ACES	Asia Cellular Satellite System
ACRV	Assured Crew Return Vehicle
ADEOS	Advanced Earth Observation Satellite
ALD	Ariane Light Derivative
ALFLEX	Automatic Landing Flight Experiment
ALOS	Advanced Land Observing Satellite
AMAS	Advanced Millimeter Wave Atmospheric Sounder
AMOS	Affordable Module Optimized Satellite
AMPTE	Active Magnetospheric Particle Tracer Explorer
AOTS	Advanced Orbital Test Satellite
APAS	Androgynous Peripheral Docking Assembly
APEKS	Active Plasma Experiment
APPLE	Ariane Passenger Payload Experiment
APT	Asia Pacific Telecommunications
APT	Automatic Picture Transmission
ARB	Emergency Locator Beacon
ARD	Atmospheric Reentry Demonstrator
ARTEMIS	Advanced Relay Technology Mission
ARTES	Advanced Research in Telecommunications Systems
ASAP	Ariane Structure for Auxiliary Payloads
ASAT	Anti-satellite
ASC	Afro-Asian Satellite Communications
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ASLV	Augmented Satellite Launch Vehicle
ATLAS	Atmospheric Lab for Applications and Science
ATSR	Along-Track Scanning Radiometer
ATV	Automated Transfer Vehicle
AUOS-SM	Automatic Universal Orbital Station
AUS	Advanced Upper Stage
BNSC	British National Space Centre (British Space Agency)
BS	Broadcasting Satellite
BSB	British Satellite Broadcasting
BSE	Broadcasting Satellite Experimental
CAC	China Aerospace Corporation
CALVT	China Academy of Launch Vehicle Technology

CARINA	Capsula di Rientro Non Abitata
CASIMIR	Catalyst Studies for Industry through Microgravity Research
CAST	China Academy of Space Technology
CBERS	China-Brazil Earth Resources Satellite
CCD	Charge Coupled Device
CERISE	Characterisation de l'Environnement Radio-electrique par un Instrument Spatial Embarque
CESAR	Central European Satellite for Advanced Research
CGWIC	China Great Wall Industry Corporation
CINC	Commander in Chief
CIS	Commonwealth of Independent States
CLS	Collecte Localisation Satellites
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CNSA	China National Space Administration
COBRAS	Cosmic Background Radiation Satellite
COF	Columbus Orbital Facility
COSIMA	Crystallization of Organic Substances in Microgravity Application
COMETS	Communications and Broadcasting Engineering Test Satellite
COSMO	Constellation for Mediterranean Observation
COSPAS	Search and Rescue Satellite
CROCODILE	Croissance de Cristaux Organiques par Diffusion Liquide dans l'Espace
CS	Communications Satellite
CSE	Evry Center for Space
CSG	Guiana Center for Space
CST	Toulouse Center for Space
CTM	Cryogenic Transfer Module
CTV	Crew Transport Vehicle
CZ	Chang Zheng (Long March)
DARA	Deutsche Agentur fur Raumfahrtangelegenheiten (German Space Agency)
DASA	Deutsche Aerospace
DCP	Data Collection Platform
DCST	Data Collection System Transponder
DEW	Directed Energy Weapon
DFH	Dongfanghong (East is Red)
DFS	Deutsche Fernmeldesatellit
DGA	Delegation Generale pour l'Armement
DLR	German Aerospace Research Establishment

DORIS	Doppler Orbitography and Radio-positioning Integrated Satellite
DRS	Data Relay Satellite
DRTS	Data Relay and Tracking Satellite
DRTM	Data Relay and Technology Mission
DSAT	Defensive Satellite
EAC	European Astronauts Center
ECS	European Communications Satellite
ECS	Experimental Communications Satellite
EGS	Experimental Geodetic Satellite
ELDO	European Launcher Development Organization
ELINT	Electronic Intelligence
ELM	Experiment Logistics Module
EMIR	European Microgravity Research Program
EMP	Electromagnetic Pulse
EMS	European Mobile Services
ENEA	National Department of Energy and Environment
ENVISAT	Environmental Satellite
EORSAT	Electronic Intelligence (ELINT) Ocean Reconnaissance Satellite
EPOS	Experimental Manned Orbital Airplane
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ESOC	European Space Operations Center
ESRIN	European Space Research Institute
ESRO	European Space Research Organization
ESTEC	European Space Research and Technology Center
ETS	Engineering Test Satellite
EUMETSAT	European Meteorological Satellite (Organization)
EURECA	European Retrievable Carrier
EUTELSAT	European Telecommunications Satellite (Organization)
EVA	Extra-Vehiclur Activity
EXOSAT	European X-ray Observatory Satellite
EXPRESS	Experimental Re-entry Space System
FEL	Free-Electron Laser
FESTIP	Future European Space Transportation Investigations Program
FGAN	Forschungsgesellschaft fur Angewardte Naturwissenschaften (German Defense Research Organization)
FGB	Functional Cargo Block

FIRST	Far Infrared and Submillimeter Space Telescope
FOBS	Fractional Orbit Bombardment System
FOV	Field of View
FSW	Fanhui Shi Weixing (Return Test Satellite)
GARP	Global Atmospheric Research Program
GDP	Gross Domestic Product
GEO	Geosynchronous Earth Orbit
GEO-IK	Geodetic Satellite - Interkosmos
GEOS	Geostationary Satellite
GFZ	GeoForschungsZentrum
GIE	Groupement d'Interet Economique
GLONASS	Global Navigation Satellite System
GMS	Geostationary Meteorological Satellite
GMT	Greenwich Mean Time
GOMS	Geostationary Operational Meteorological Satellite
GPS	Global Positioning System
GSLV	Geosynchronous Satellite Launch Vehicle
GSOC	German Space Operations Center
GTO	Geosynchronous Transfer Orbit
HEOS	Highly Eccentric Orbit Satellite
HIMES	Highly Maneuverable Experiment Space
HIPPARCOS	High Precision Parallax Collecting Satellite
HOPE	H-II Orbiting Plane
HORUS	Hypersonic Orbital Reusable Upper Stage
HOTOL	Horizontal Take-Off and Landing
HRPT	High Resolution Picture Transmission
HST	Hubble Space Telescope
HTP	Hypersonics Technology Program
HYFLEX	Hypersonics Flight Experiment
IAI	Israel Aircraft Industries Ltd
ICAO	International Civil Aviation Organization
ICBM	Intercontinental Ballistic Missile
IKI	Institute of Space Research, Russian Academy of Sciences
IML	International Microgravity Laboratory
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite (Organization)
INSAT	Indian Satellite

INTA	National Institute for Aerospace Technology
INTEGRAL	International Gamma-Ray Astrophysics Laboratory
INTELSAT	International Telecommunications Satellite (Organization)
IR	Infra-red
IRAS	Infra-Red Astronomical Satellite
IRE	Institute of Radio Engineering and Electronics
IRIS	Italian Research Interim Stage
IRS	Indian Remote Sensing Satellite
ISA	Israeli Space Agency
ISAS	Institute of Space and Aeronautical Science
ISEE	International Sun-Earth Explorer
ISO	Infrared Space Observatory
ISRO	Indian Space Research Organization
ISS	International Space Station
ISTI	International Space Technology Inc.
ISTP	International Solar Terrestrial Physics
ITALSAT	Italian Satellite
ITAMSAT	Italian Amateur Satellite
ITU	International Telecommunications Union
IUE	International Ultraviolet Explorer
IZMIRAN	Institute of Terrestrial Magnetism, Ionosphere, and Radio-wave Propagation
JCSAT	Japanese Communications Satellite
JEM	Japanese Experiment Module
JERS	Japanese Earth Resources Satellite
KIK	Space Command, Control, and Tracking System
KOMSAT	Korea Multipurpose Satellite
KORONAS	Complex Orbital Near-Earth Observations of Activity of the Sun
LAGEOS	Laser Geodynamics Satellite
LAPS	Liquid Apogee Propulsion System
LEO	Low Earth Orbit
LISS	Linear Imaging Self-Scanner
LOX	Liquid Oxygen
LUT	Local User Terminal
MAKS	Multi-purpose Aerospace System
MARECS	Maritime European Communications Satellite
MAU	Millions of Accounting Units
MBB	Messerschmitt-Bolkow-Blohm

MEASAT	Malaysian East Asia Satellite
MEOSS	Monocular Electro-Optical Stereo Scanner
MESSR	Multi-spectral Electronic Self-Scanning Radiometer
MIPAS	Michelson Interferometer for Passive Sounding
MITI	Ministry of International Trade and Industry
MOMS	Modular Optoelectronic Multi-spectral Stereo Scanner
MOP	Meteosat Operational Program
MORO	Moon Orbiting Observatory
MOS	Marine Observation Satellite
MPLM	Mini Pressurized Logistics Module
MSG	Meteosat Second Generation
MSR	Microwave Scanning Radiometer
MSU	Multi-Spectral Unit
MTSAT	Multi-functional Transport Satellite
MURST	Ministry of Universities and Scientific and Technological Research
N <sub>2</sub> O <sub>4</sub>	Nitrogen Tetroxide
NAL	National Aerospace Laboratory
NASDA	National Space Development Agency of Japan
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NIKA	Scientific Research Spacecraft
NKAU	National Space Agency of Ukraine
NPO	Scientific Production Association
OICETS	Optical Inter-Orbit Communications Engineering Test Satellite
ONERA	Office National d'Etudes et de Recherches Aérospatiales
OREX	Orbiting Re-entry Experiment
OTS	Orbital Test Satellite
PAKSAT	Pakistan Satellite
PAL	Propulseur d'Appoint Liquide
PAP	Propulseur d'Appoint Poudre
PKO	Anti-Space Defense
PM	Pressurized Module
PO	Production Association
POEM	Polar-Orbiting Earth Observation Mission
POLDER	Polarization and Directionality of the Earth's Reflectance
PoSAT	Portugal Satellite
PPEM	Plan Pluriannuel d'Espace Militaire

PRARE	Precision Range and Range Rate Experiment
PRC	People's Republic of China
PRO	Anti-Missile Defense
PSDE	Payload and Spacecraft Demonstration and Experimentation Program
PSLV	Polar Satellite Launch Vehicle
PSN	Pasifik Satellit Nusantara
PT	Posts and Telecommunications
PTT	Platform Transmitter Terminal
PVO	Troops of Air Defense
RAMOS	Russian-American Observation Satellite
REC	Radio Electronic Combat
RKA	Russian Space Agency
RKK	Rocket Space Corporation
RORSAT	Radar Ocean Reconnaissance Satellite
ROSAT	Roentgensatellit (X-ray satellite)
ROSIS	Reflective Optics Imaging Spectrometer
ROSTO	Russian Defense, Sport, and Technical Organization
RT	Radio Telescope
RTG	Radioisotope Thermoelectric Generator
SAC	Space Activities Commission
SAFIR	Satellite for Information Relay
SAGE	Stratospheric and Aerosols and Gas Experiment
SAR	Synthetic Aperture Radar
SARA	Satellite for Amateur Radio Astronomy
SARIT	Satellite di Radiodiffusione Italiana
SAPS	Solar Activity Patrol System
SAX	Satellite Astronomia raggi-X
SBL	Space-Based Laser
SCARAB	Scanner for Radiation Budget
SCC	Space Communications Corporation
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Chartography
SDRN	Satellite Data Relay Network
SEDEX	Synthese Enzymatique de Dextrane
SEM	Space Environment Monitor
SEP	Societe Europeenne de Propulsion
SES	Societe Europeenne des Satellites
SEU	Single Event Upset

SFU	Space Flyer Unit
SHF	Super High Frequency
SHAR	Sriharikota High Altitude Range
SICRAL	Sistema Italiana de Comunicazione Riservente Allarmi
SLBM	Submarine-Launched Ballistic Missile
SLV	Satellite Launch Vehicle
SOHO	Solar and Heliospheric Observatory
SPAS	Shuttle Pallet Satellite
SPAS	Solar Patrol and Alert Satellite
SPELDA	Structure Porteuse pour Lancements Double Ariane
SPELTRA	Structure Porteuse Externe de Lancements Triples Ariane
SPM	Space Processing Module
SPOT	Satellite Pour l'Observation de la Terre
SPRN	Missile Attack Warning System
SROSS	Stretched Rohini Satellite Series
SSC	Swedish Space Corporation
SSME	Space Shuttle Main Engine
SSS	Space Surveillance System
SSTL	Surrey Satellite Technology Ltd
SSTO	Single Stage To Orbit
STARS	Seismic Telescope for Astrophysical Research from Space
START	Strategic Arms Reduction Treaty
STEP	Satellite Test of the Equivalence Principle
STIVC	Secondary Injection Thrust Vector Control System
STRV	Space Technology Research Vehicle
STS	Space Transportation System
STSP	Solar/Terrestrial Science Program
SUPARCO	Space and Upper Atmosphere Research Commission
SWIR	Short Wavelength Infra-red Radiometer
SYLDA	Système de Lancement Double Ariane
SYRACUSE	Système de Radio Communications Utilisant un Satellite
TDF	Telediffusion de France
TEMISAT	Telespazio Micro Satellite
TMP	Engineering Production Module
TOMS	Total Ozone Mapping Spectrometer
TRMM	Tropical Rainfall Measuring Mission
TsDKC	Long-Range Space Communications Center



TsNPO	Central Scientific Production Association
TSS	Tethered Satellite System
TsUP	Flight Control Center
TT&C	Tracking, Telemetry, and Control
TUBSAT	Technical University of Berlin Satellite
UARS	Upper Atmosphere Research Satellite
UDMH	Unsymmetrical Dimethylhydrazine
UHF	Ultra High Frequency
UK	United Kingdom
UoSAT	University of Surrey Satellite
US	United States
USEF	Institute for Free Flyer Unmanned Space Experiments
USP	Unified Space Platform
USSR	Union of Soviet Socialist Republics
UV	Ultra-violet
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VHRSR	Very High Resolution Scanning Radiometer
VISSR	Visible and Infra-red Spin Scan Radiometer
VKS	Military Space Forces
VNIIEM	All-Russian Electromechanical Scientific Research Institute
VNIR	Visible and Near-Infra-red Radiometer
VSOP	VLBI (Very Long Baseline Interferometry) Space Observatory Program
VTIR	Visible and Thermal Infra-red Radiometer
WEU	Western European Union
XMM	X-Ray Multi-Mirror Satellite
X-SAR	X-Band Synthetic Aperture Radar



## 1.0 PRINCIPAL SPACE ORGANIZATIONS AND INFRASTRUCTURE

The high technology requirements associated with space activity, including satellite and launch vehicle design, manufacture, and operations, dictate a comprehensive and well defined organization involving both government and industry whether the program is of a national or commercial nature. This section highlights the major agencies and support functions which are necessary for the realization of the spacecraft and the space transportation systems described herein. Only the principal sponsors of space endeavors in Europe and Asia which have broad interest and influence in space activities have been selected (Table 1.1). Figure 1.1 indicates the relative activities of Europe and Asia in space versus the United States.

### 1.1 EUROPEAN SPACE AGENCY

Since its official establishment in 1975, the European Space Agency (ESA) not only has become the most prominent force in the commercial space launch services market but

also has invested substantial resources in developing and operating scientific and applications (Earth observation, communications, meteorology, and materials processing) space systems. Although ESA's ambitious plans to perform independent manned space operations have faltered during the 1990's, a long-term commitment remains. For a decade ESA has been the third most active space-faring organization in the world behind the USSR/CIS and the US.

From an initial membership of 11 nations, by 1994 ESA included 13 full members (Austria, Belgium, Denmark, France, Germany, Iceland, Italy, The Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom), one associate member (Finland), and one cooperating state (Canada). Finland was to become a full member in January, 1995. Portugal and Greece may apply for membership in ESA during the next several years. The purpose of ESA is to "provide for and to promote, for exclusively peaceful purposes,

TABLE 1.1 PRINCIPAL EURASIAN SPACE INFRASTRUCTURES.

NATIONAL CIVILIAN AGENCY	ESTABLISHED	HEAD (31 DEC 1994)	LAUNCH SITES	LAUNCH VEHICLES	PROGRAM PRIORITIES
EUROPEAN SPACE AGENCY (ESA)	1975	JEAN-MARIE LUTON	****	ARIANE 4	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, SCIENCE, MANNED SPACE FLIGHT, MICROGRAVITY
CENTRE NATIONAL D'ETUDES SPATIALES (CNES)	1962	RENE PALLET	KOUROU	****	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, MANNED SPACE FLIGHT
DEUTSCHE AGENTUR FÜR RAUMFAHRTANGELEGENHEITEN (DARA)	1989	JAN-BALDEM MENNICKEN	****	****	EARTH OBSERVATION, COMMUNICATIONS, SCIENCE, MICROGRAVITY
INDIAN SPACE RESEARCH ORGANIZATION (ISRO)	1969	KRISHNASWAMY KASTURIRANGAN	SRIHARIKOTA	ASLV, PSLV	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, SCIENCE
ISRAELI SPACE AGENCY (ISA)	1983	YUVAL NE'EMAN	PALMACHIM	SHAVIT	SPACE TRANSPORTATION, SPACE TECHNOLOGY
AGENZIA SPAZIALE ITALIANA (ASI)	1988	GIORGIO FIOCCO	SAN MARCO	****	SPACE TRANSPORTATION, SCIENCE, GEODESY, MANNED MODULES
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN (NASDA)	1969	MASATO YAMANO	KAGOSHIMA TANEGASHIMA	M-3SII H-II	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, SCIENCE
CHINA NATIONAL SPACE ADMINISTRATION (CNSA)	1993	LIU JIYUAN	JIUQUAN TAIYUAN XICHANG	CZ-2C, CZ-2D CZ-4 CZ-2E, CZ-3, CZ-3A	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, MICROGRAVITY
RUSSIAN SPACE AGENCY (RKA)	1992	YURI KOPTEV	BAIKONUR PLESETSK	MOLNIYA, PROTON, ROKOT, SOYUZ KOSMOS, MOLNIYA, SOYUZ, START 1	SPACE TRANSPORTATION, EARTH OBSERVATION, COMMUNICATIONS, MANNED SPACE FLIGHT, SCIENCE, NAVIGATION, GEODESY, MICROGRAVITY
NATIONAL SPACE AGENCY OF UKRAINE (NIKAU)	1992	ANDREI ZHALKO-TYTARENKO	****	TSYKLON, ZENIT	SPACE TRANSPORTATION, EARTH OBSERVATION
BRITISH NATIONAL SPACE CENTRE (BNSC)	1985	DEREK DAVIS	****	****	EARTH OBSERVATION, COMMUNICATIONS

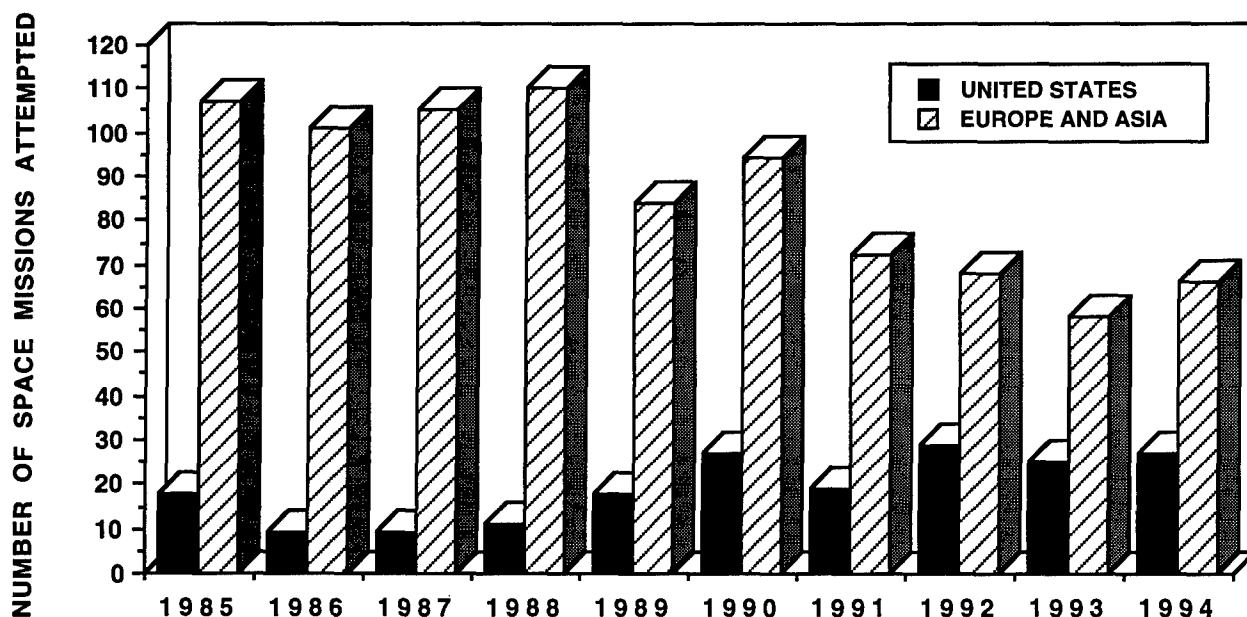


FIGURE 1.1 WORLD-WIDE SPACE LAUNCH ACTIVITY.

cooperation among European States in space research and technology and their space applications, with a view to their being used for operational space applications systems" (Reference 1). Although cooperation with other national and international space organizations has been encouraged, one of the tenets of ESA policy has been to maximize European independence in virtually all matters of space exploration and exploitation.

The ESA organizational structure includes a Council for policy decisions and approval of long-range plans and a much larger operations arm for handling the day-to-day affairs of the agency. The Council, led since July, 1993, by Chairman Pieter Gaele Winters of the Netherlands, is divided into Program Boards and Committees staffed by national delegations. Whereas the Council normally meets once each quarter, full ministerial-level meetings are held about every other year or as dictated by events. As a result of significant world political changes and economic factors, ministerial-level meetings were held in 1991 (Munich) and 1992 (Granada) with the next meeting scheduled for 1995.

ESA operations are managed by the Director General, Jean-Marie Luton of France (since October, 1990), and his principal staff which includes five major technical directorates: Science, Telecommunications, Observation of the Earth and Its Environment, Manned Spaceflight and Microgravity, and Launchers

(Figure 1.2). With headquarters in Paris and liaison offices in Washington, DC; Kourou, French Guiana; and Toulouse, France, ESA runs four major facilities with a combined staff of about 2,000 permanent employees (Figure 1.3).

The European Space Operations Center (ESOC) established in September, 1967, is the primary satellite control facility for ESA spacecraft. Located in Darmstadt, Germany, and headed by Director Felix Garcia-Costaner, ESOC operates detachments in French Guiana, Belgium, Germany, and Spain and receives additional assistance from national ground stations in the Canary Islands, Sweden, Italy, Kenya, Australia, and Japan. Daily control of spacecraft such as Meteosat, IUE, ECS, and MARECS is handled by ESOC as well as support for international spacelab missions on the US Space Shuttle. Upgrades at several ground stations were underway in 1994 to support major missions like Ulysses, ERS, Cluster, and ISO (References 2-3).

The European Space Research and Technology Center (ESTEC) in Noordwijk, Netherlands, houses more than half of all ESA personnel in its role as the satellite environmental testing facility. Under the direction of Marius Le Fevre, ESTEC is organized into five principal departments: Systems Engineering and Programmatics, Mechanical Systems, Electrical Systems, Automation and Informatics, and Product Assurance and Safety.

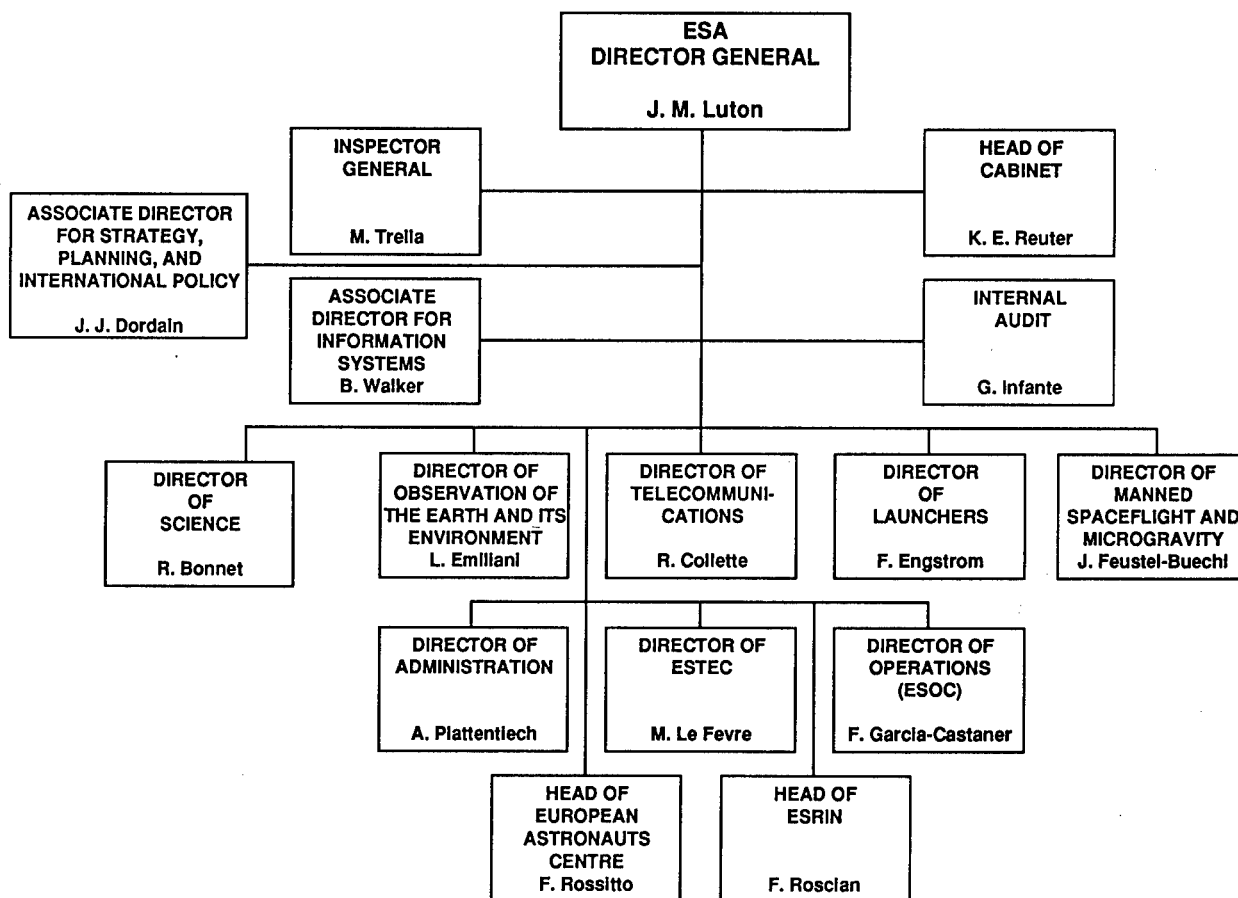


FIGURE 1.2 ESA DIRECTORATE ORGANIZATIONAL STRUCTURE.

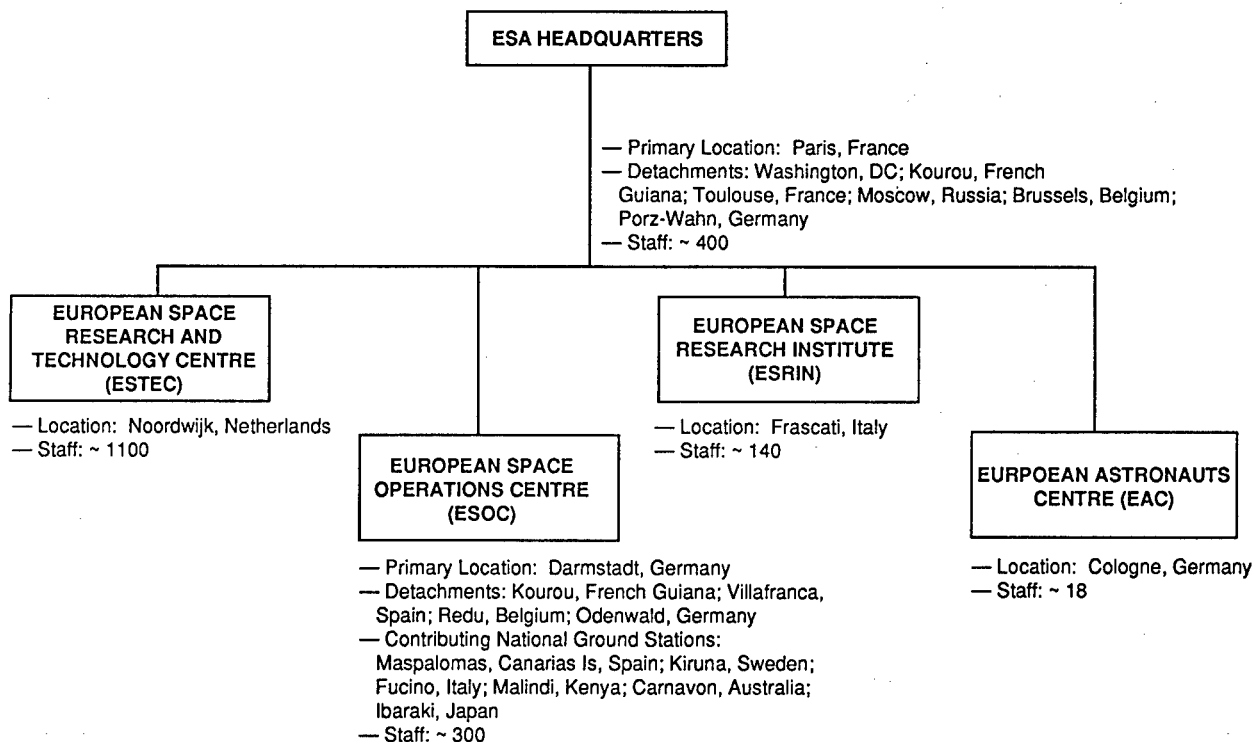


FIGURE 1.3 MAJOR ESA CENTERS AND FACILITIES.

Operational since 1968, ESTEC services national and commercial spacecraft as well as ESA satellites (References 4-7).

The oldest of ESA's main centers is the European Space Research Institute (ESRIN), established in Frascati, Italy, in 1966 by ESA's predecessor, the European Space Research Organization. ESRIN, with a staff of 140 led by Francis Roscian, manages the ESA Information Retrieval Service (ESA-IRS), Earthnet, and the Information Systems Division. At ESRIN's Earth Observation Data Handling Center, remote sensing data from the European Remote Sensing Satellite (ERS) as well as US and Japanese Earth observation satellites are received, processed, archived, and disseminated (References 8-11).

The European Astronauts Center (EAC) in Cologne, Germany, is the newest and smallest of the four ESA centers. Approved at the ESA Ministerial meeting of 1987, EAC began limited operations in 1990 in anticipation of major ESA manned space flight requirements in support of the Hermes spaceplane and International Space Station programs. With the cancellation of the former and substantial delays associated with the latter, EAC's growth has been stymied, and by 1994 the permanent staff, headed by Franco Rositto, was only about 20% of the anticipated 100 personnel. However, EAC was assisting in the preparation of the ESA-Russian Euromir 94 and Euromir 95 missions to the Mir space station and Spacelab flights (References 12-13).

Although ESA developed the Ariane family of launch vehicles, the organization does not own a space launch facility. Instead, Ariane launches are conducted from the French Guiana Space Center under special

arrangement with ESA. ESA also does not maintain its own aerospace industry, choosing to contract with the specialized companies of its member states to procure most spacecraft and launch vehicle components. To finance its many endeavors and infrastructure, ESA members contribute to mandatory programs based upon Gross Domestic Product (GDP) and to voluntary programs. In both cases, however, ESA attempts to redistribute its funds in proportion to the contributions of its members.

Table 1.2 delineates the ESA payment appropriations for 1993 and 1994. Taking into account inflationary factors, both years represent a real decline from the 1992 appropriation budget of 2967.4 MAU. However, some programs, e.g., "Earth Observation and its Environment," enjoyed significant budget increases, largely possible by the declining development costs of the Ariane 5 launch vehicle. The ESA budgeting process continues to be plagued by fluctuating currency exchange rates (References 14-15).

## 1.2 FRANCE

For more than three decades, France has led continental Europe's push into space and was instrumental in the creation of ESA and its predecessor ESRO. France's first satellite, Asterix, was launched by a domestic booster from a French military base in Algeria. France has been a strong promoter of European space independence but has not hesitated to take advantage of opportunities to cooperate with the larger US and Soviet/Russian space programs. France continues to pursue a broad selection of national, bilateral, and ESA-sponsored programs and is taking the lead in Europe in developing military space systems.

TABLE 1.2 ESA PAYMENT APPROPRIATION, 1993-1994.

PROGRAM	1993	1994
SPACE TRANSPORTATION	1262.4 MAU (41.9%)	902.4 MAU (32.2%)
MANNED SPACE FLIGHT	372.9 MAU (12.4%)	353.9 MAU (12.6%)
EARTH OBSERVATION	324.6 MAU (10.8%)	467.1 MAU (16.7%)
TELECOMMUNICATIONS	303.5 MAU (10.1%)	277.4 MAU ( 9.9%)
SCIENCE	299.0 MAU ( 9.9%)	334.7 MAU (11.9%)
MICROGRAVITY	68.2 MAU ( 2.3%)	69.9 MAU ( 2.5%)
OTHER (General Budget, etc.)	383.1 MAU (12.7%)	398.2 MAU (14.2%)

MAU = MILLION ACCOUNTING UNITS; 1 AU = 1 EUROPEAN CURRENCY UNIT (ECU)

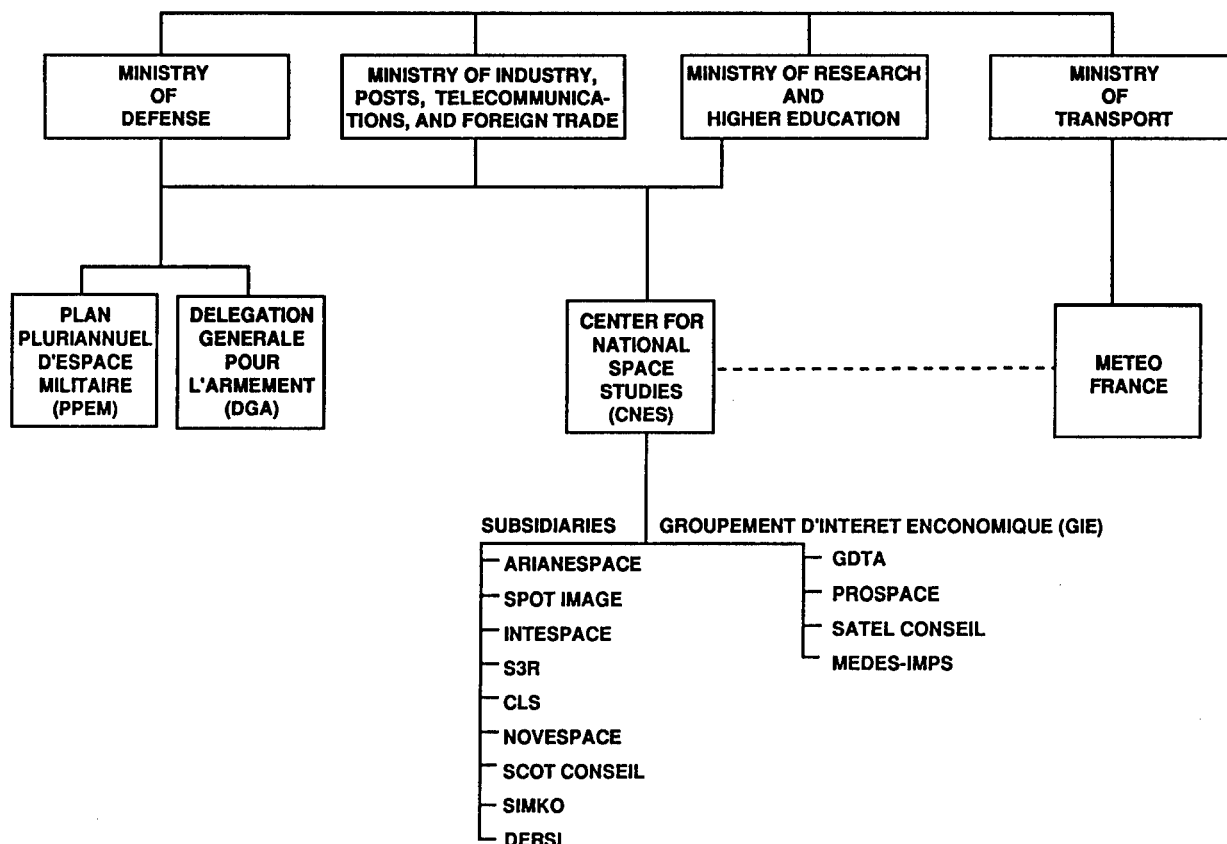


FIGURE 1.4 FRENCH NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

The French civilian space program is managed by the Centre National d'Etudes Spatiales (CNES), which was established in 1962. The principal objectives of CNES are four-fold: "(1) orienting the French space program by preparing Government decisions, (2) designing, managing, and conducting the actual programs in an industrial context, (3) furthering the know-how of France's space industry, and (4) consolidating research programs with the scientific community" (Reference 16).

After a change in government in March, 1993, the following month CNES was placed under joint supervision by the Ministry of Higher Education and Research, the Ministry of Defense, and the Ministry of Industry, Posts, Telecommunications, and Foreign Trade. Gerard Longuet, the head of the last mentioned ministry, assumed the portfolio of Space Minister, only to be replaced by Jose Rossi in October, 1994. An indirect path from the Ministry of Transport via Meteo France also leads to CNES for coordination of meteorological activities (Figure 1.4).

With a contingent of nearly 2,500 personnel, the CNES staff outnumbers its ESA counterpart. Led by President Rene Pallet since November, 1992, CNES is managed by Director General Jean-Daniel Levi. Pallet's term expired in October, 1994, but he remained in office at the end of the year as a successor was still being sought. Previous CNES Director Generals have moved on to assume top positions within the French government, including the Minister for Research and Space and Chief of the Delegation General pour l'Armement of the Ministry of Defense, as well as the head of ESA, e.g., Jean-Marie Luton. Reporting to the Director General are seven principal directorates: (1) Programs, (2) International Relations, (3) Long Term Analysis and Assessment, (4) Astronauts, (5) Industry and Technical Policy, (6) Quality Assurance, and (7) Communications.

Analogous to ESA, CNES operates four major centers (Figure 1.5). The largest by far is the Toulouse Space Center, home to approximately 1,650 personnel. Operations

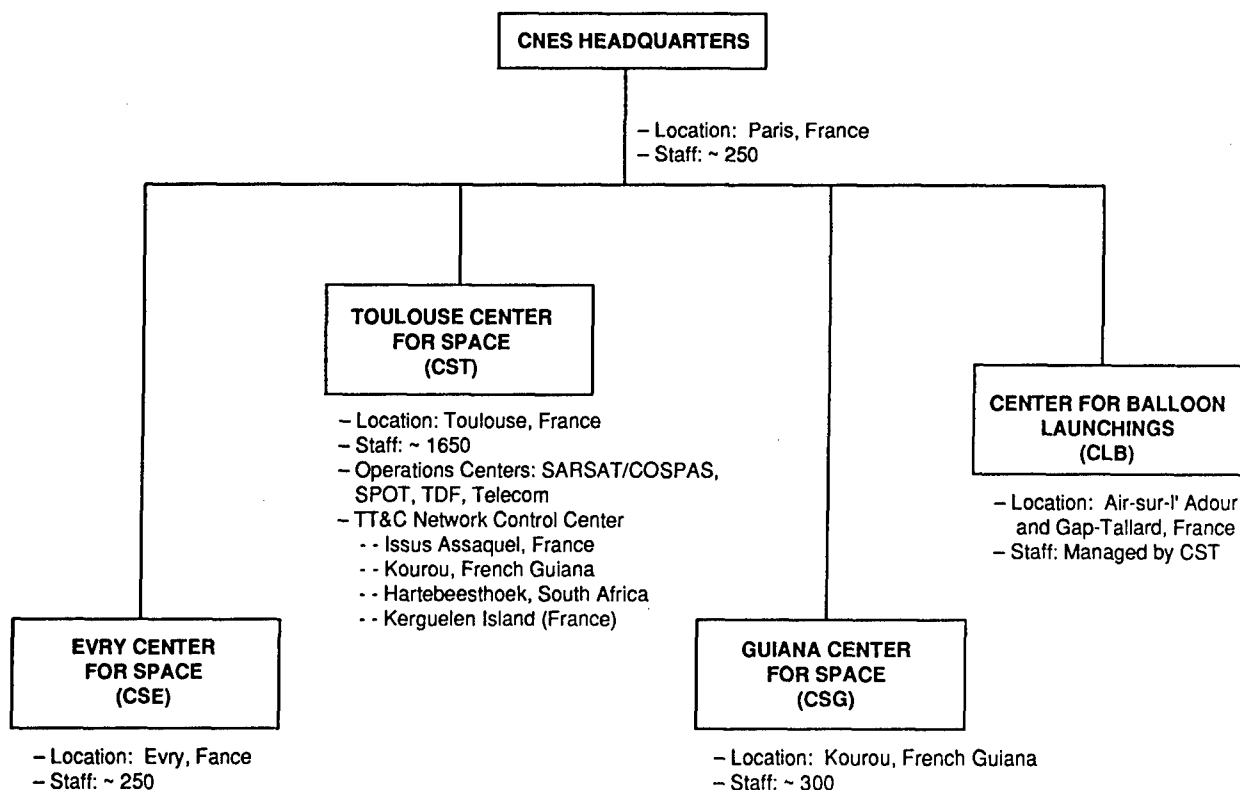


FIGURE 1.5 MAJOR CNES CENTERS AND FACILITIES.

centers for SPOT, TDF, and Telecom are located at Toulouse, which also directs tracking, telemetry, and communications control centers at Issus Aussaquel, France; Kourou, French Guiana; Hartebeesthoek, South Africa, and Kerguelen Island. The Guiana Center for Space at Kourou, French Guiana, provides full launch support services for all ESA Ariane space launches, while the Evry Center for Space is the headquarters for Arianespace, the CNES subsidiary responsible for managing much of the Ariane program. A fourth CNES center is in charge of atmospheric balloon launchings.

In its role as promoter of the French aerospace industry, CNES has established a number of subsidiaries and special organizations called GIEs (Groupements d'Interet Economiques). The best known subsidiaries include Arianespace, SPOT Image, Intespace, and Novespace. The principal aerospace industries in France include Aerospatiale (spacecraft, subsystems, and materials), Alcatel Espace (communications, subsystems, and TT&C), Arianespace (launch vehicles), Dassault Aviation (manned aerospace vehicles), Intespace (environmental

testing), Matra Marconi Space (spacecraft, subsystems, and ground stations), SEP (launch vehicle and spacecraft propulsion), and Thomson-CSF (communications, space technology, and ground support). In 1994 Matra Marconi Space acquired British Aerospace Space Systems to form the largest European space industry. In late 1994 Aerospatiale and Germany's DASA were negotiating a potential merger of their space divisions.

The CNES budget authority continued to grow in 1993 and 1994, but the increases were essentially neutralized by inflation. The final budget for 1994 was 11.997 billion French Francs or 11.662 billion French Francs after government taxes. This latter amount was distributed among five sectors: space transportation (40.3%), space applications (24.1%), science (14.4%), future programs (4.5%), and general support (16.8%). Just over 40% of the CNES budget is earmarked for France's contribution to ESA. Meanwhile, the French military space budget grew from 3.5 billion French Francs in 1992 to 4.1 billion French Francs in 1994 (References 17-18).



### 1.3 GERMANY

Under a major governmental restructuring in 1989-1990, a new German space agency, DARA (Deutsche Agentur für Raumfahrtangelegenheiten) GmbH, was created and seven national space goals were established:

- increase scientific knowledge of the universe, our solar system, the Earth and the conditions for life on our planet and to enlarge the possibilities for research;
- contribute to solving environmental problems by means of Earth observation satellites and promote further world climate research;
- improve public and commercial infrastructure and services by means of spacebound telecommunications, positioning and navigation;
- stimulate technological progress and thereby contribute to improving the competitiveness of the German economy;
- make access to space and its utilization safer and more economic;
- promote international cooperation especially in the field of science and technology and improve the possibilities of extending aid to developing countries;

- realize the verification and control of treaties covering disarmament, crisis management and Earth observation for environmental purposes alongside our European partners."

DARA, which assumed and consolidated the activities of the former West and East German space agencies, is headed by a Director General and is staffed by a group of only about 285 personnel. The founding Director General of DARA, Prof. Dr. Wolfgang Wild, retired in the Fall of 1993 and was replaced on 1 October by Dr. Jan-Baldem Mennicken, former Chairman of DARA's Supervisory Board and member of the Ministry for Research and Technology. National long-range planning and oversight of DARA is achieved by the Cabinet Committee and the State Secretary's Committee formed by representatives of seven ministries and the Federal Chancellery (Figure 1.6). With its limited resources, DARA is largely restricted to policy and top level management tasks (Reference 19). During 1993-1994 DARA underwent an internal reorganization emerging with four major technical directorates: (1) Space Science and Infrastructure System, (2) Earth

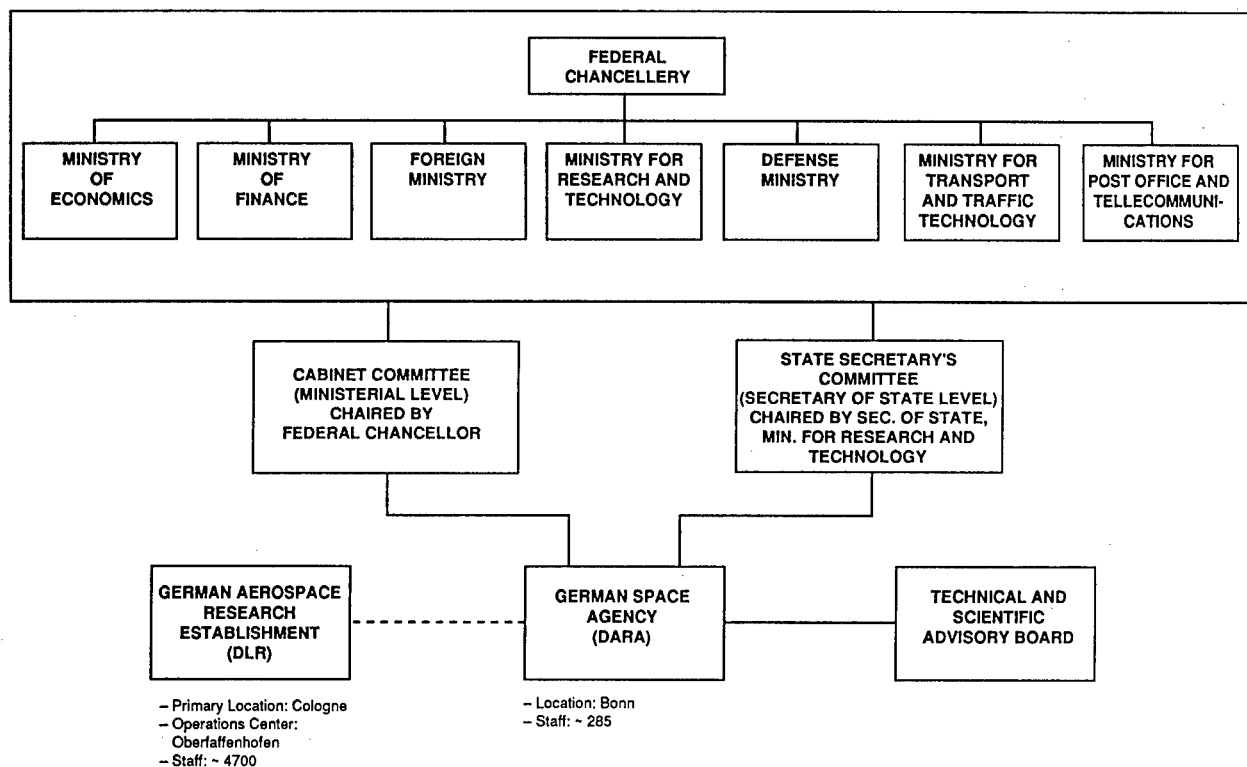


FIGURE 1.6 GERMAN NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

Observation and Telecommunications, (3) Industrial Affairs and Engineering, and (4) Budget and Strategic Planning.

While DARA is instrumental in establishing space policy and goals and is the interface with ESA, the German Aerospace Research Establishment (DLR, Deutsche Forschungsanstalt für Luft und Raumfahrt) conducts the technical and scientific research and performs the operational support required to implement that policy. DLR was formed in 1969 with the merger of national aerospace research and test organizations as DFVLR but was reorganized and renamed in 1989 at the time DARA was created. One of the consequences of this reorganization was the transfer of major program management functions from DLR to DARA.

With approximately 4,700 personnel led by Chairman Walter Kroell, DLR is involved in a broad spectrum of basic and applications research in addition to operations, and as the name implies the organization's charter includes activities which are not space-related. In fact, these non-space endeavors account for approximately one half of the annual DLR budget. Headquartered in Cologne, DLR is divided into six major directorates: (1) Flight Mechanics and Guidance and Control, (2) Fluid Mechanics, (3) Materials and Structures, (4) Energetics, (5) Telecommunications Technology and Remote Sensing, and (6) Scientific-Technical Facilities (Reference 20).

DLR operates major research centers in Braunschweig, Cologne-Porz, Gottingen, Oberpfaffenhofen, and Stuttgart. Oberpfaffenhofen is the home of the German Space Operations Center which has supported numerous national, ESA, and bi-lateral space missions for more than 20 years. Nearby are DLR's Manned Space Laboratories Control Center, User Data Center, and Automation in Orbit Center. The Crew Training Complex and the Microgravity User Support Center are located in Cologne-Porz. Germany is also the site of two of ESA's four major space centers: the European Space Operations Center in Darmstadt and the new European Astronauts Center in Cologne.

Although Germany lacks a domestic space transportation system or launch facility, the nation is the only non-Russian European country to possess a credible, albeit limited, space surveillance capability. The German

Defense Research Organization (FGAN, Forschungsgesellschaft für Angewandte Naturwissenschaften) operates the High Power Radar System consisting of a 34-m diameter dish antenna, an L-band tracking radar, and a Ku-band imaging radar. Located at Wachtberg-Werthoven outside Bonn and housed within a 49-m diameter radome, this system can perform selected observations on objects in Earth orbit (Reference 21).

The nature of the German aerospace industry changed significantly at the beginning of the decade when the formation of Deutsche Aerospace (DASA) brought together some of the most influential space manufacturing firms. DASA's four subsidiaries are now Dornier (unmanned and manned space systems), Messerschmitt-Bölkow-Blohm (MBB; spacecraft, subsystems, and ground support equipment), Motoren- und Turbinen-Union (MTU; propulsion), and Telefunken Systemtechnik (subsystems, materials). As noted in the previous section, the Space Systems Group of DASA may merge with Aerospatiale in the near future. Other important aerospace companies include ANT Nachrichtentechnik GmbH (communications spacecraft, subsystems), MAN Technologie (space vehicle engineering), and Siemens (communications, subsystems). The firm Kayser-Threde GmbH specializes in microgravity research and is a major facilitator in the European exploitation of Russian space technology.

The German national budget for space activities grew slightly in 1993 to 1.8 billion Deutsche Marks but fell back to 1.6 billion Deutsche Marks in 1994. Moreover, slightly more than two-thirds of the 1994 appropriation was designated as Germany's contribution to ESA. Space Science commands the highest priority of the basic technical disciplines. Surprisingly, Germany's military space budget, which to date has been exceedingly minor, may soon rival the civilian budget with a projected 10 billion Deutsche marks spent over the 1995-2004 period (References 19, 22-24).

#### 1.4 INDIA

Despite its limited resources, India has and is continuing to develop a broad-based space program with indigenous launch vehicles, satellites, control facilities, and data processing. Since its first satellite was orbited by the USSR in 1975 and its first domestic space launch was

conducted in 1980, India has become a true space-faring nation and an example to other Eurasian countries wishing to move into the space age. Today's Indian remote sensing, communications, and meteorological satellites are comparable to many similar space systems operated by more affluent countries, and by the end of the decade India may be one of only a half dozen countries/organizations with a geostationary launch capability.

The Indian Space Research Organization (ISRO) was established in 1969 and is currently under the Department of Space (Figure 1.7). An inter-ministerial Space Commission coordinates space-related issues at the highest government levels for policy-making and implementation through the Department of Space and ISRO. Along with ISRO in the Department of Space are the National Remote Sensing Agency, the National Natural Resources Management System, the National Mesosphere-Stratosphere-Troposphere Radar Facility, and the Physical Research Laboratory. The Chairman of ISRO since 1984, Prof. U. R. Rao, stepped down and was replaced in April, 1994 by Krishnaswamy Kasturirangan, who also carries the titles Secretary of the Department of

Space and Chairman of the Space Commission. With headquarters at Bangalore, ISRO now boasts of a workforce of approximately 17,000 (References 25-27).

ISRO oversees five major centers and various units. The largest facility is the Vikram Sarabhai Space Center at Trivandrum, near the southern tip of India, where emphasis is placed on propulsion and launch vehicle technology as well as spacecraft subsystems. The ISRO Satellite Center in Bangalore is the lead center for all satellite development. All Indian space launches originate from the Sriharikota High Altitude Range (SHAR) Center on Sriharikota Island in the Bay of Bengal. The Liquid Propulsion Systems Center is actually distributed among facilities at Bangalore, Mahendragiri, and Trivandrum. Finally, the Space Applications Center at Ahmedabad has the responsibility to ensure that practical applications of space technology are realized. ISRO also operates a Telemetry, Tracking, and Command Network for satellite control (Reference 28).

A large portion of India's aerospace expertise remains within ISRO, but a commercial industry continues to be nurtured.

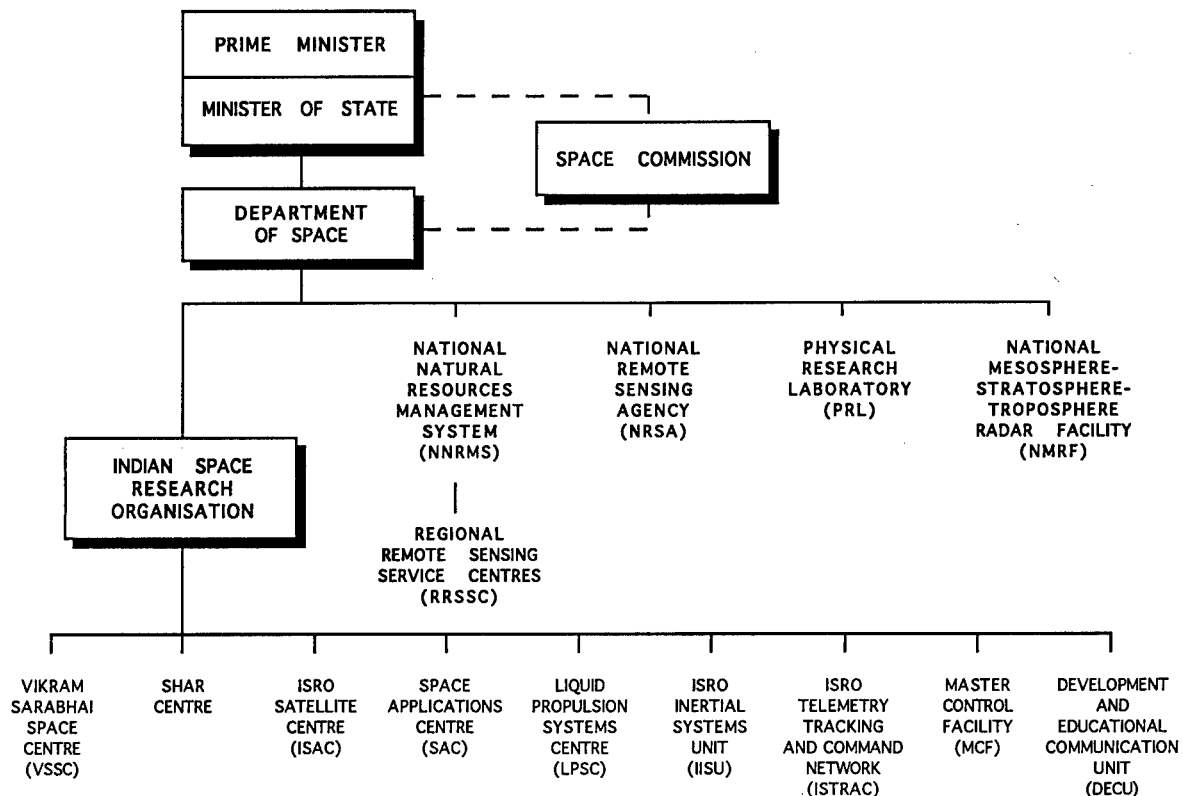


FIGURE 1.7 INDIAN NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

ISRO created the Antrix Corporation in 1992 to market space and telecommunications products, and in the same year established a policy to promote the commercial procurement of space technology components rather than their manufacture within ISRO. Today, approximately 50% of the ISRO budget goes to Indian industry, although a subsequent portion may be used to purchase foreign equipment. Facilities construction and development are often provided by a separate Civil Engineering Division of the Department of Space (References 25, 29-30).

The annual ISRO space budget period runs from 1 April to the following 31 March. From the 1993-1994 budget year, appropriations increased by about 12% to nearly 8 billion Rupees (compared with approximately 5 billion Rupees for 1992-1993) with an even sharper increase forecast for the following year. Slightly more than 40% of the annual outlays are designated for launch vehicle development and operations. A separate government allotment is given to the Antrix Corporation which is not yet self-sufficient.

### 1.5 ISRAEL

The newest member of the so-called space club is Israel which has conducted only two successful space launches, the first in 1988 and the other in 1990. Following in the footsteps of India, Israel is first concentrating on the development of relatively simple launch vehicles with low payload capacity and of satellites based on proven technologies. Future activities may be biased toward the deployment of more sophisticated space systems (via domestic and commercial foreign launch services) rather than a significant advance in booster capability.

The Israeli Space Agency (ISA) was created in 1983 under the Ministry of Science and Technology and is chaired by Prof. Yuval Ne'eman. The Director General of ISA, Aby Har-Even, manages the agency in its duties to run the nation's space program, to coordinate research and space studies, and to promote the "development of space-related products by the private sector" (References 31-32). Cooperating with ISA to exploit Israel's fledgling capabilities in space are the Interdisciplinary Center for Technological Analysis and Forecasting of Tel Aviv University and the National

Committee for Space Research of the Israeli Academy of Sciences and Humanities.

To date Israel's industrial base for launch vehicle and satellite development is narrow. Israel Aircraft Industries Ltd (IAI) was the principal designer and manufacturer of the Shavit solid-propellant booster and the Ofeq experimental spacecraft and is developing the Amos geostationary communications satellite. Rafael, Israel Armament Development Authority, was responsible for the AUS-51 which has served as the third stage motor of Shavit launch vehicle. The Asher Space Research Institute of the Technion Institute of Technology is developing the small Techsat (aka Gurwin-1), a 50-kg class satellite scheduled for launch in 1995, and El-Op Electro-optics Industries specializes in spaceborne sensors.

The official ISA annual budget is only about \$50 million, but this does not cover launch vehicle development or most satellite programs. Instead, Israeli industry is making substantial investments in space technology, while the Ministry of Defense underwrites much of the infrastructure, including the Shavit launch vehicle and the Palmachim launch facility (References 33-36).

### 1.6 ITALY

Italy was one of the first European nations to operate its own Earth satellite (launched by the US in 1964), and during 1967-1988 the nation conducted nine launches from the San Marco Indian Ocean platform with the assistance of the US. Despite significant achievements in space science, geodesy, and manned spacecraft modules, Italian progress in space exploration and exploitation has slowed considerably during the 1990's as national fiscal constraints and bureaucratic upheavals have taken their toll.

A governmental reorganization in 1988 established the Italian Space Agency (ASI, Agenzie Spaziale Italiana) under the Ministry of Universities and Scientific and Technological Research (MURST) and its Undersecretary of Space (Figure 1.8). Beginning in 1992 ASI came under intense scrutiny for its budgetary and program management handlings. Shortly after the appointment of Umberto Colombo to the post of Minister of MURST in May, 1993, ASI's long-time President, Luciano Guerriero,

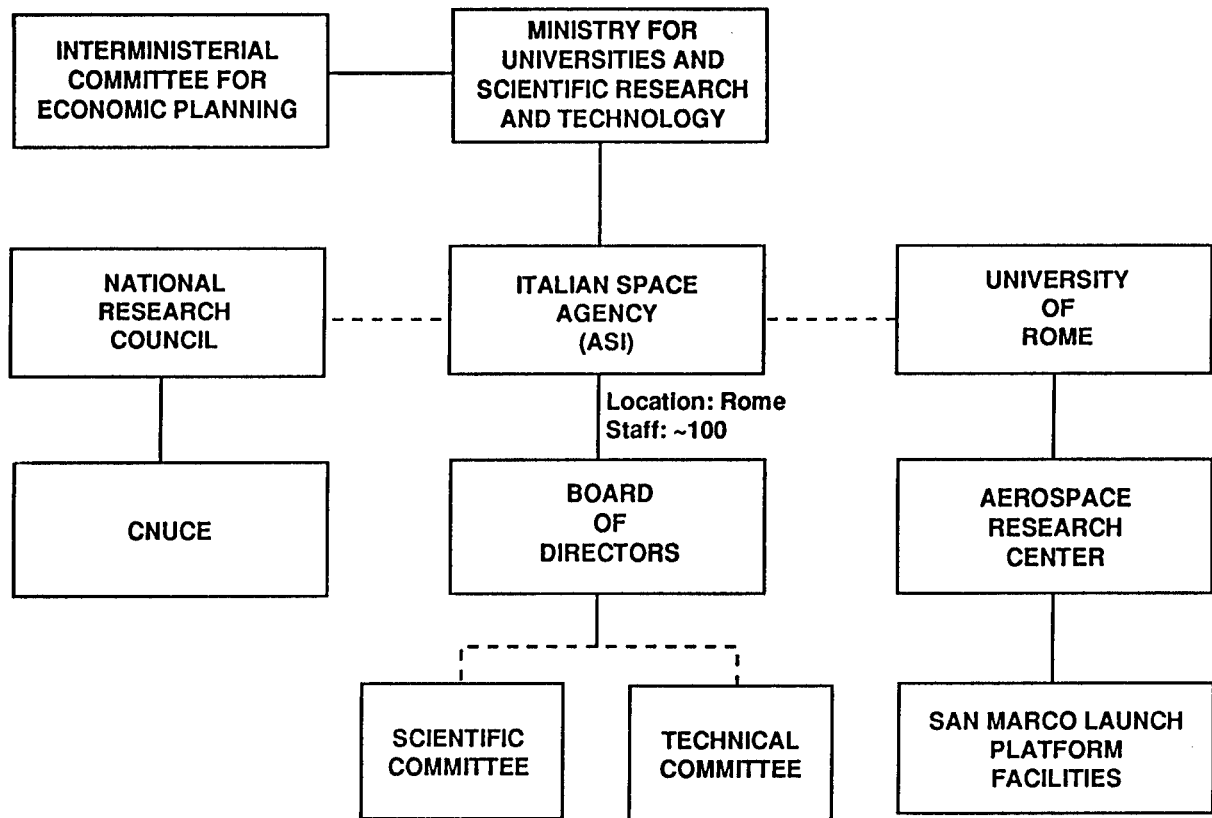


FIGURE 1.8 ITALIAN NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

and Director General, Carlo Buongiorno, left the agency. On 1 September 1993, Giampietro Puppi, a past president of ESRO, assumed duties as interim commissioner of ASI. Then, in February, 1994, Giorgio Fiocco, a professor at the University of Rome, was selected as the new president of ASI. Later, Prof. Mario Calamia, was tapped to be ASI's Director General. However, in late September, 1994, the Italian government announced its intention to transfer ASI from MURST to the National Department of Energy and Environment (ENEA) in June, 1995 (References 37-45).

ASI is a relatively small organization with a staff of little more than 100 personnel and headquarters in Rome. The agency's Board of Directors is advised by two 12-person committees: the Scientific Committee and the Technical Committee. To implement the national space program ASI works closely with the University of Rome and the National Research Council. The former, through its Aerospace Research Center, manages the San Marco space launch facility in the Indian Ocean near Kenya. However, relations between ASI and the University of Rome became strained in 1991-1992 over

different views concerning the means of improving Italy's space launch capability. No Italian space launches have occurred since 1988 as the nation continues to wrestle with the development of a Scout follow-on. The National Research Council, through its CNUCE institute, supports ASI in areas of mission analysis, mission design, and data handling, and works with Italian aerospace industries.

With assistance from ASI, the Italian government adopts 5-year space plans to establish national goals and for long-range budgeting purposes. The guidelines proposed for the 1990-1994 Italian national space plane included:

- significant importance of fundamental research, toward which 15% of the national financing activity is dedicated, in compliance with the law constituting the ASI...
- strong impetus toward development of industrial type activity...
- reinforcement of initiatives aimed at favoring installation in the South, of new structures having high technological content and with the potential to have a broad impact on the production apparatus...

- consolidation of educational and training activity aimed at the need within the space sector to encourage qualitative growth of the human factor in national enterprises and research structure which, faced with the European reality, are in no way adequate or large enough;
- substantial balancing between national activity and Italian participation in ESA...
- strong characterization at the international level...
- promotion of initiatives tending toward an increasingly efficient coordination with national administrations and agencies dedicated to the fulfillment of operational activity connected with the development of space activities..."

The principal Italian corporation involved in space activities is Alenia Spazio which was formed in 1990 with the merger of Aeritalia and Selenia. The new firm, responsible for approximately 70% of Italy's industrial space activities, is broad-based, supporting both Italian and European programs with spacecraft, subsystems, ground stations, and related software. BPD Difesa E Spazio is Italy's leading company for launch vehicle and spacecraft propulsion.

The 1990-1994 five-year plan had envisioned substantial increases in ASI's annual budget, from 1.0 trillion Lira in 1990 to 2.1 trillion Lira in 1994. However, national fiscal constraints capped the annual allocations to 0.8 trillion Lira for each of 1992, 1993, and 1994, while inflation and the devaluation of the Lira have actually reduced the real value of the

budget. To offset both the budget shortfall and the effects of inflation, ASI has been granted the authority to borrow money, e.g. 0.7 trillion Lira for the period 1993-1994. Italian law requires that 15% of the ASI budget be expended for basic scientific research, but in recent years the interpretation of that mandate has led to serious internal governmental disputes. Nearly 50% of the 1994 budget was set aside for space transportation and International Space Station activities in nearly equal amounts. Despite the fact that the proportion of the Italian space budget earmarked for ESA has risen from less than 50% in 1991 to nearly 75% in 1994, Italy has experienced difficulties in meeting its obligations as ESA's third major member. In 1994 ESA agreed to loan funds to Italy in the amount of 0.19 billion Lira over a three-year period (Reference 46-49).

## 1.7 JAPAN

Japan is unique among the Eurasian space nations with two, relatively independent national space organizations: one for applications and one for science. Both not only fund and manage satellite programs but also develop families of launch vehicles and maintain separate launch facilities to place the satellites in orbit. The government structure is further complicated by the various ministries and agencies which support these organizations (Figure 1.9). The Space Activities Commission (SAC) annually reviews Japan's Space Development Program to coordinate national space activities and to draft departmental

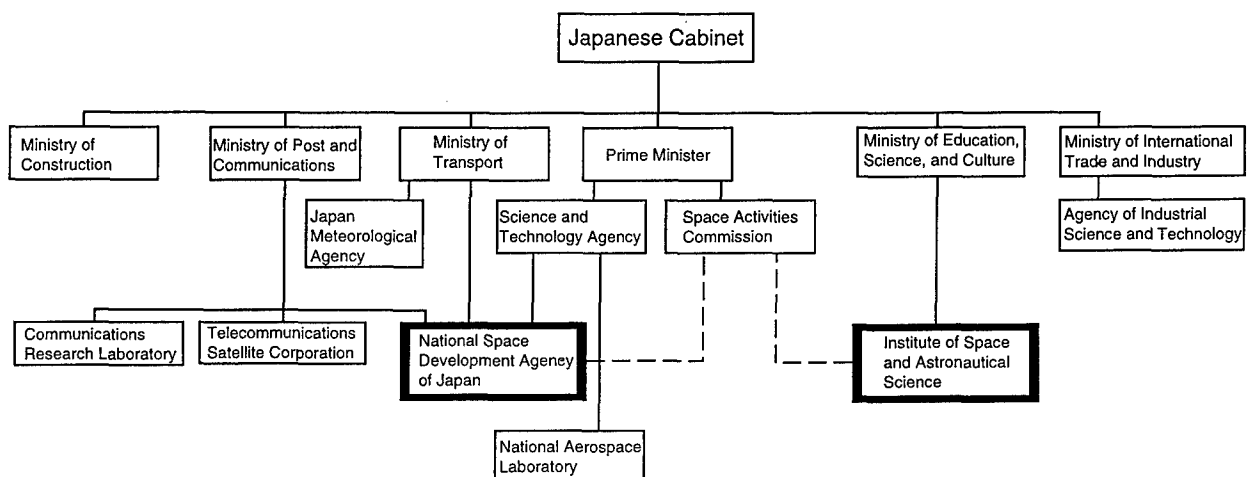


FIGURE 1.9 JAPANESE NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

budgets. The chairman of SAC is the Minister of State for Science and Technology. Since the first domestic launch of a Japanese satellite in 1970, the country has become a major space power, perhaps surpassed in all Europe and Asia by only the Russian Federation and the multi-national ESA (References 50-51).

The National Space Development Agency of Japan (NASDA) currently receives about 75% of the national space budget primarily via the Science and Technology Agency of the Prime Minister's Office, the Ministry of Transport, and the Ministry of Posts and Telecommunications. NASDA, with a workforce of nearly 1,000 personnel, is responsible for the development of Japanese communications, meteorological, and Earth observation satellites as well as the large H-class launch vehicles. NASDA also oversees Japan's participation in the International Space Station and is behind the proposed HOPE spaceplane. The President of NASDA since 1990, Masato Yamano, supervises five major technical offices: Space Utilization, Space Transportation, Satellites, Earth Observation, and Research and Development (Figure 1.10). NASDA operates several large space centers

including the Tanegashima Space Center for space launches, the Kakuda Propulsion Center for the development of launch vehicle propulsion systems, the Tsukuba Space Center for satellite tracking and control, and the Earth Observation Center for data processing of remote sensing information (References 52).

Working under the Ministry of Education, the Institute of Space and Aeronautical Science (ISAS) is devoted to space science research and the development of satellite and launch vehicle, e.g., M-3SII, technologies needed to support this objective. Until 1981 ISAS was a part of the University of Tokyo. The Director General of ISAS, Ryojiro Akiba (since February, 1992), heads 11 technical divisions with 300 staff and 100 graduate students and is advised by a Board of counselors and an Advisory Council for Research and Management (Figure 1.11). ISAS' primary facilities include the Kagoshima Space Center for space launches, the Noshiro Testing Center for launch vehicle propulsion system development, and the Usuda Deep Space Center with a 64-m diameter antenna for satellite tracking and control (References 53-56).

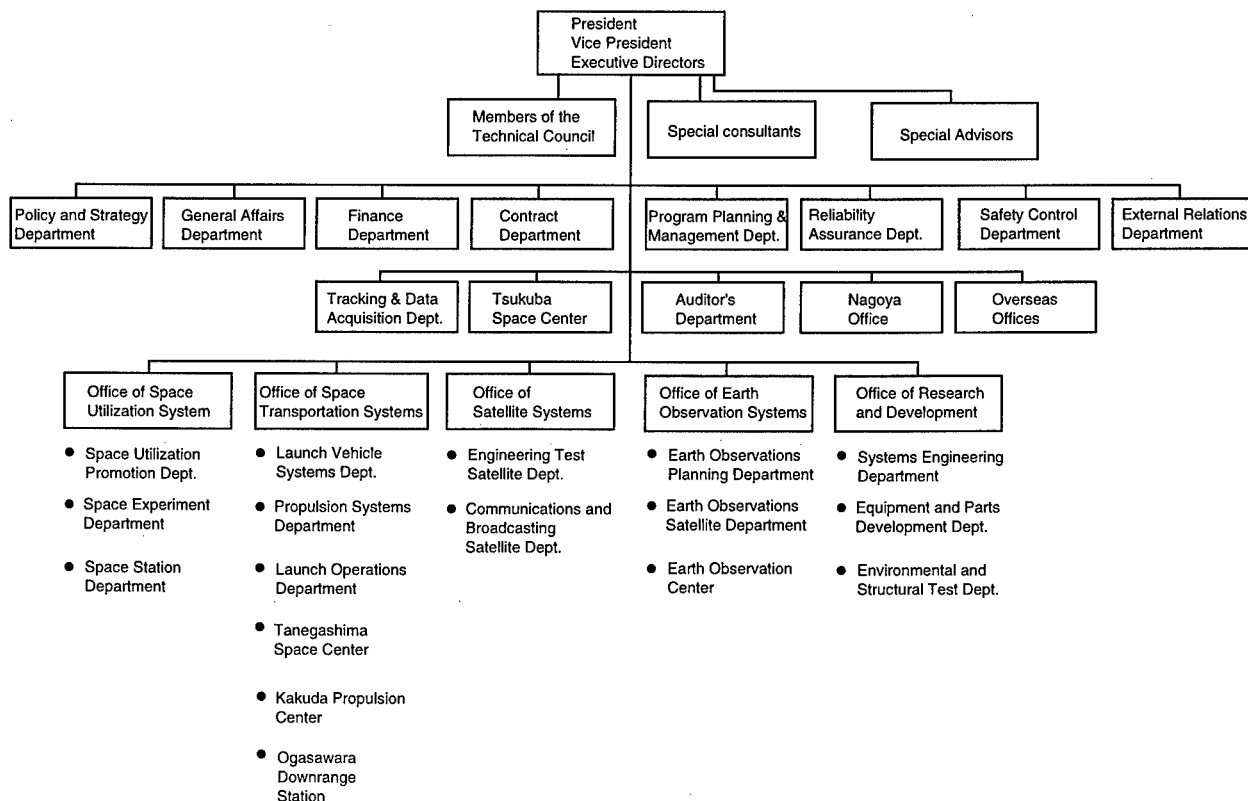


FIGURE 1.10 NASDA ORGANIZATIONAL STRUCTURE.

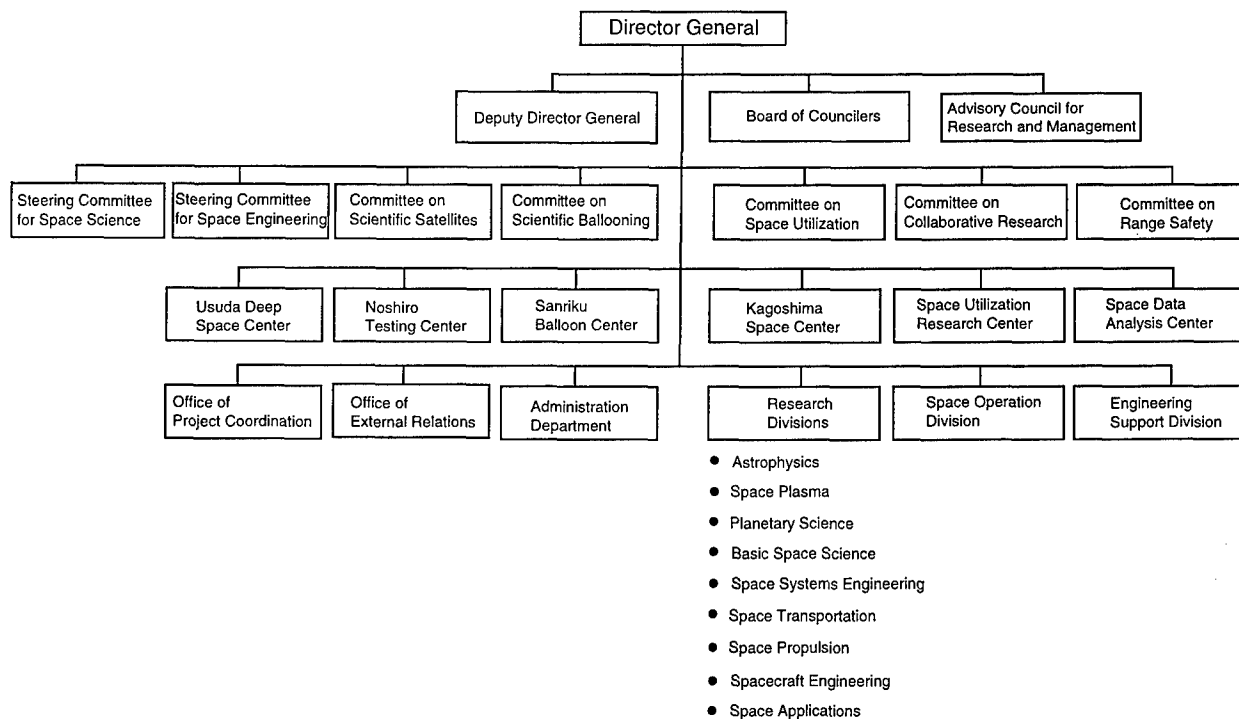


FIGURE 1.11 ISAS ORGANIZATIONAL STRUCTURE.

In 1963 Japan's National Aeronautical Laboratory was reorganized into the National Aerospace Laboratory (NAL) with the incorporation of a space division. As its name implies, the NAL conducts research with a wide range of atmospheric and space systems with an emphasis on airframe and propulsion technologies. As a subordinate organization to the Science and Technology Agency, NAL often supports NASDA programs, e.g., in the development of the LE-5 and LE-7 main engines for the H-II launch vehicle. The Director General of NAL is Kazuaki Takashima with responsibility for 450 staff (75% involved in research) in numerous divisions and groups. The Space Technology Research Group is further divided into 13 subgroups covering all major space technologies. From headquarters in Tokyo, NAL operates the Kakuda Research Center, associated with NASDA's Kakuda Propulsion Center (References 57-59).

Japan benefits from a strong interest in space activities by the giants of industry. Moreover, these firms invest considerable private resources to conceive long-term projects which may not be realized for a decade or more. Mitsubishi Heavy Industries and Nissan Motor Company are the major launch vehicle manufacturers for NASDA and ISAS,

respectively. Mitsubishi Electric Corporation, Nippon Electric Corporation, and Toshiba Corporation all have credentials as satellite prime contractors. Fuji Heavy Industries Ltd. and IHI Company Ltd. both support development of reusable space transportation systems and the Japanese Experiment Module for the International Space Station. Sumitomo Heavy Industries is well known for launch vehicle support facilities, and Shimizu Corporation is leading industry in the design of long-range facilities, including outposts on the Moon and Mars.

By 1994, the Japanese government was investing in excess of \$2.5 billion annually, and, as space budgets in the West decline, Japanese expenditures continue to experience real growth. The total space budget increased nearly 15% between 1992 and 1994, reaching almost 230 billion Yen. During this same period, NASDA's budget increased 17% to 164 billion Yen, but ISAS's budget increased only 3% to 21 billion Yen. Of the record 12 billion Yen allocated to NAL during 1994, 4.5 billion Yen constituted the space budget.

## 1.8 PEOPLE'S REPUBLIC OF CHINA

The PRC's first domestic space launch took place just two months after Japan's first mission



in 1970, and since then the paths of these two Asian countries have been remarkably similar. Like Japan, the PRC averages only a few missions each year and has developed the means to reach both LEO (including sun-synchronous missions) and GEO. However, the PRC has launched relatively few scientific satellites and has accumulated extensive experience with recoverable spacecraft.

In 1968 the China Academy of Space Technology (CAST) was formed to manage the technical development and application of space launch vehicles and spacecraft. Until recently, this extensive program was directed principally by the Ministry of Aerospace Industry (1988-1993), but a major reorganization in 1993 affected most of the aerospace industry. By the end of 1994 the China Aerospace Corporation (CAC or CASC) and the China National Space Administration (CNSA) had assumed the authority previously held by the Ministry of Aerospace Industry (Figure 1.12). However, the two new organizations are not independent, sharing a number of responsibilities as well as personnel. For example, the President of CAC, Liu Jiyuan, is also the Administrator of CNSA. Liu Jiyuan was formerly the Vice Minister of the Aerospace Industry and the Vice President of CAST and is a graduate of the Bauman

Polytechnic University in Moscow. The principal role of CNSA is to serve as PRC's interface with other national space agencies, while CAC exerts primary control over the national space program (References 60-63).

CAST has retained its responsibility for the design and manufacture of most Chinese satellites, e.g., recoverable, communications, and scientific spacecraft, and operates a number of institutions and factories to meet satellite development and testing requirements. Meteorological spacecraft are created by the Shanghai Academy of Spaceflight Technology's Shanghai Institute of Satellite Engineering, which until 1993 was also a part of CAST. During the 1980's the Shanghai Academy of Spaceflight Technology, then known as the Shanghai Bureau of Astronautics (founded in 1969), supervised 10 research institutes and 12 factories with a workforce of more than 30,000 for the production of both spacecraft and launch vehicles.

Launch vehicle construction is largely divided between the Shanghai Academy of Spaceflight Technology and the China Academy of Launch Vehicle Technology (CALVT), formerly the Wan Yuan Industry Corporation, founded in 1957. The Shanghai Academy of Spaceflight Technology builds the

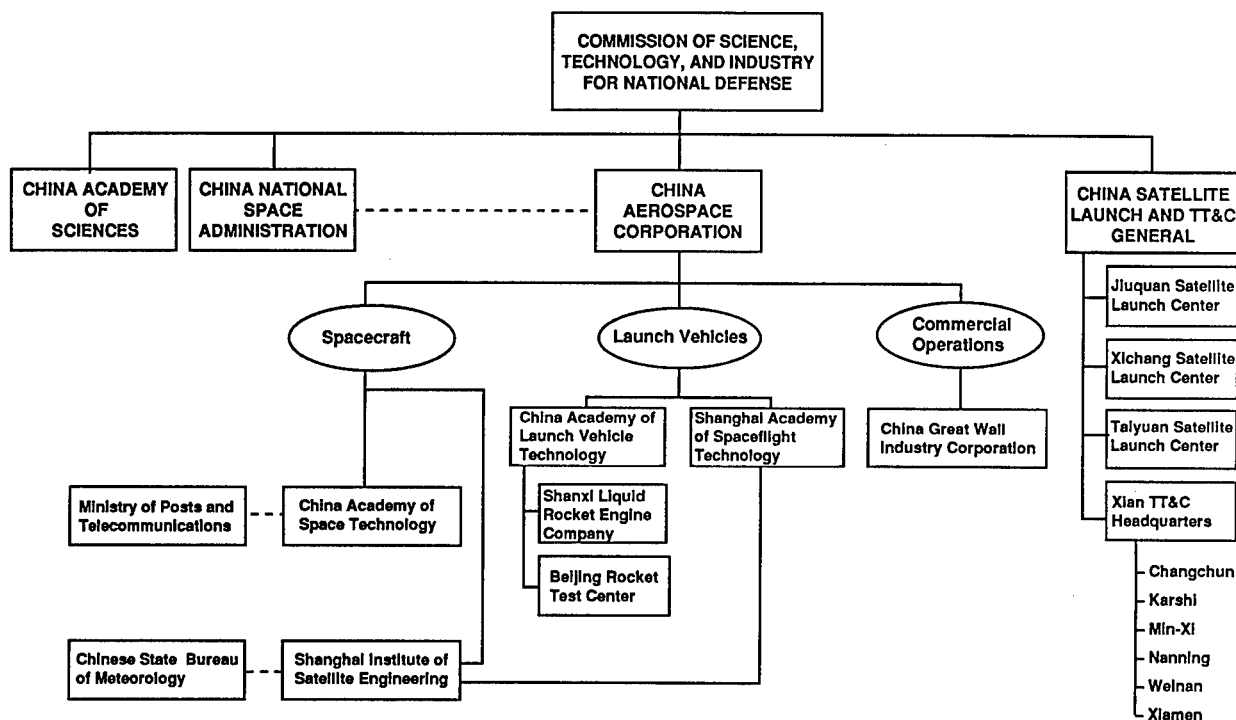


FIGURE 1.12 CHINESE NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

first and second stage structures of the CZ-3 launch vehicle and is responsible for the CZ-2D and CZ-4 boosters, while CALVT managed the development of the CZ-2C and hypergolic and cryogenic engines. Solid propellant retro motors and apogee kick motors have been developed by the Northwest Chemistry Dynamics Corporation, and spacecraft thrusters are built by the Beijing Institute of Control Engineering and the China Academy of Sciences' Lanzhou Institute of Physics. CAC's Hexi Company has developed a new solid propellant perigee kick stage motor scheduled for a flight in 1995.

Another major firm governed by CAC is the China Great Wall Industry Corporation (CGWIC). Established in 1980, CGWIC in 1985 was selected to handle the import and export of Chinese space technology and products with an objective to arrange for the launch of foreign spacecraft by Chinese boosters on a commercial basis. In July, 1993, the China Satellite Launch Agents of Hong Kong Ltd. was established to promote the commercial use of Chinese recoverable spacecraft.

The China Satellite Launch and TT&C General organization is responsible not only for the launch of all Chinese space boosters but

also for their vital tracking, telemetry, and control functions. All three Chinese launch centers and the TT&C infrastructure come under its jurisdiction. In all, the organization claims a workforce of more than 20,000, including Luoyang Tracking and Communications Technology Center and the Beijing Special Engineering and Design Institute.

The China Academy of Sciences apparently plays a minor role in the national space program. While its institutes may contribute some components, instrumentation, and scientific experiments, the academy is rarely mentioned in reports and documents on space activities.

Until 1994 financial details of China's military and civilian space programs were considered state secrets. Moreover, the Chinese governmental budget structure, like that of the former Soviet Union, was not amenable to such specific accountings. Recently the Chinese annual budget for civil space activities, including research and development, launch vehicle and satellite production, and launch site tests, has averaged 1.4-1.5 billion Yuan. Actual launch and satellite control operations are financed separately (References 64-66).

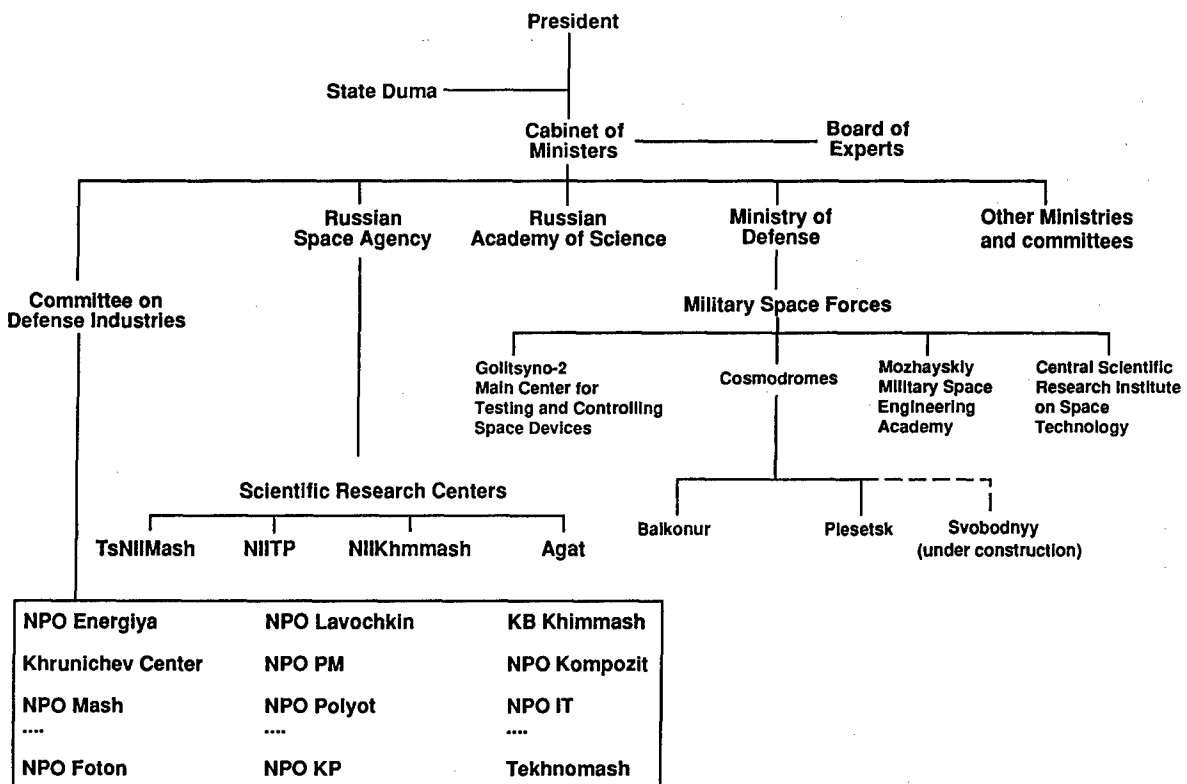


FIGURE 1.13 RUSSIAN NATIONAL SPACE ORGANIZATIONAL STRUCTURE.

## 1.9 RUSSIAN FEDERATION

For nearly 30 years the USSR was the most prolific builder and launcher of artificial satellites in the world, accounting for 68% of the 3,400 international space missions conducted from 1957 to its dissolution at the end of 1991. The sheer magnitude of this effort led to a highly structured, albeit Byzantine, system of space program development, funding, and implementation. Early plans to transform the Soviet space infrastructure into a Commonwealth of Independent States (CIS) family of space programs failed to mature, and the Russian Federation, via the Russian Space Agency (RKA) and the Russian Military Space Forces (VKS) both founded in 1992, inherited the responsibility for maintaining a diverse constellation of approximately 170 operational spacecraft and the industry behind it (Figure 1.13). A CIS Interstate Space Council still exists and sets budgets and priorities but in practice it is subservient to the Russian space program.

The RKA, led by General Director Yuri Nikolayevich Koptev, is still a relatively small

organization (few hundred personnel) with largely administrative functions, but, particularly during 1994, the agency began assuming greater power as several industrial concerns joined its modest scientific research center association (Figure 1.14). The growing number of bilateral and multilateral accords with other national space agencies, e.g., the International Space Station, has also increased the influence of the RKA. The official responsibilities of the RKA were codified in August, 1993, in the Russian Federation Law on Space (Section 7.3). During 1993 RKA drafted the long-range civilian space program objectives through the year 2000 (Section 7.4 and References 67-71).

The Russian Armed Forces were established on 7 May 1992, enabling the creation of VKS later that year on 10 August. Commander-in-Chief of the VKS is Col. Gen. Vladimir Ivanov, who was also CINC of the predecessor organization, Ministry of Defense Space Units (1982-1991), since 1989. The VKS is currently responsible for the operation of the Baikonur and Plesetsk Cosmodromes, the

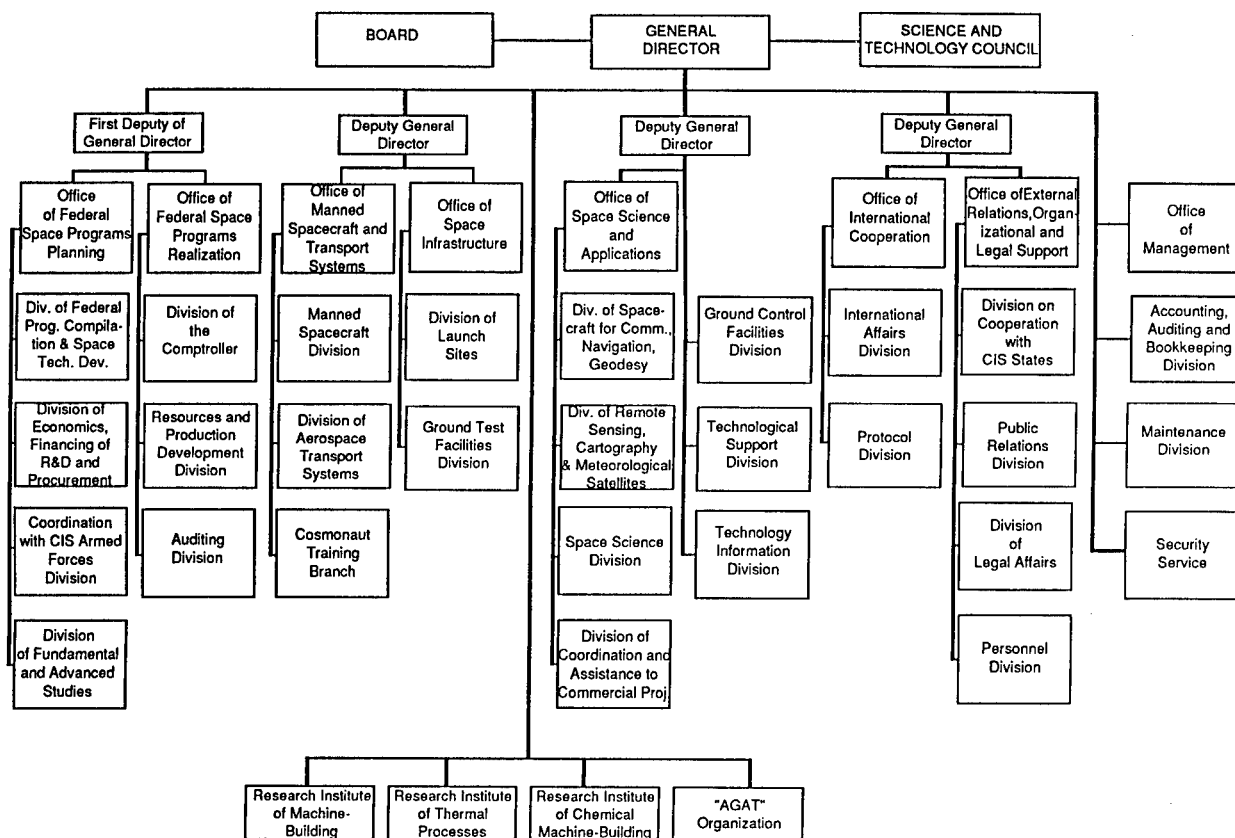


FIGURE 1.14 RKA ORGANIZATIONAL STRUCTURE.

construction of the Svobodnyy Cosmodrome, the Mozhayskiy Military Space Engineering Academy, the Central Scientific Research Institute on Space Technology, and the Space Command, Control, and Tracking System (KIK), which includes the Main Center for Testing and Controlling Space Devices at Golitsyno-2 near Moscow as well as other sites in the former Soviet Union (Figure 1.15). Portions of the KIK also support RKA's Flight Control Center (FCC or TsUP) at Kaliningrad near Moscow in conjunction with the Mir space station program. The former fleet of Space Event Support Ships operated by the former USSR Academy of Sciences has essentially been disbanded, although the Russian Ministry of Defense still operates some specialized range instrumentation ships capable of providing KIK services. In 1994, the VKS began testing a new mobile KIK unit and deploying new KIK sites to offset the loss of facilities outside the Russian Federation (References 70, 72-85).

A special network of large-diameter antennas make up the Long-Range Space Communications System (TsDKC) for control of

scientific spacecraft in high Earth orbits or on interplanetary flights. The network consists of 10 primary antennas (22-70 m diameter) at seven locations: Yevpatoriya, Simeiz, Pushchino, Medvezhi Ozera, Ulan Ude, Ussuriysk, and the Suffa Plateau (the last under construction). For example, current plans call for linking the RT-32 and RT-70 radiotelescopes at Yevpatoriya and Ussuriysk and the RT-64 radiotelescope at Medvezhi Ozera to form the primary tracking and telecommunications system for the Mars-96 mission.

Equally important as the KIK is the Russian network of large ground-based radars which form the backbone of the Russian Space Surveillance System (SSS), managed by the Air Defense Forces. Space surveillance tasks are primarily performed by Dnepr and Daryal-UM radars developed in the 1960's and 1980's, respectively. Eight facilities are intermittently operational: in Russia at Irkutsk, Murmansk, and Pechora; in Ukraine at Sevastopol and Uzhgorod; in Kazakhstan at Balkhash; in Azerbaijan at Mingechaur; and in Latvia at Riga. An unfinished Daryal-UM radar in Latvia was

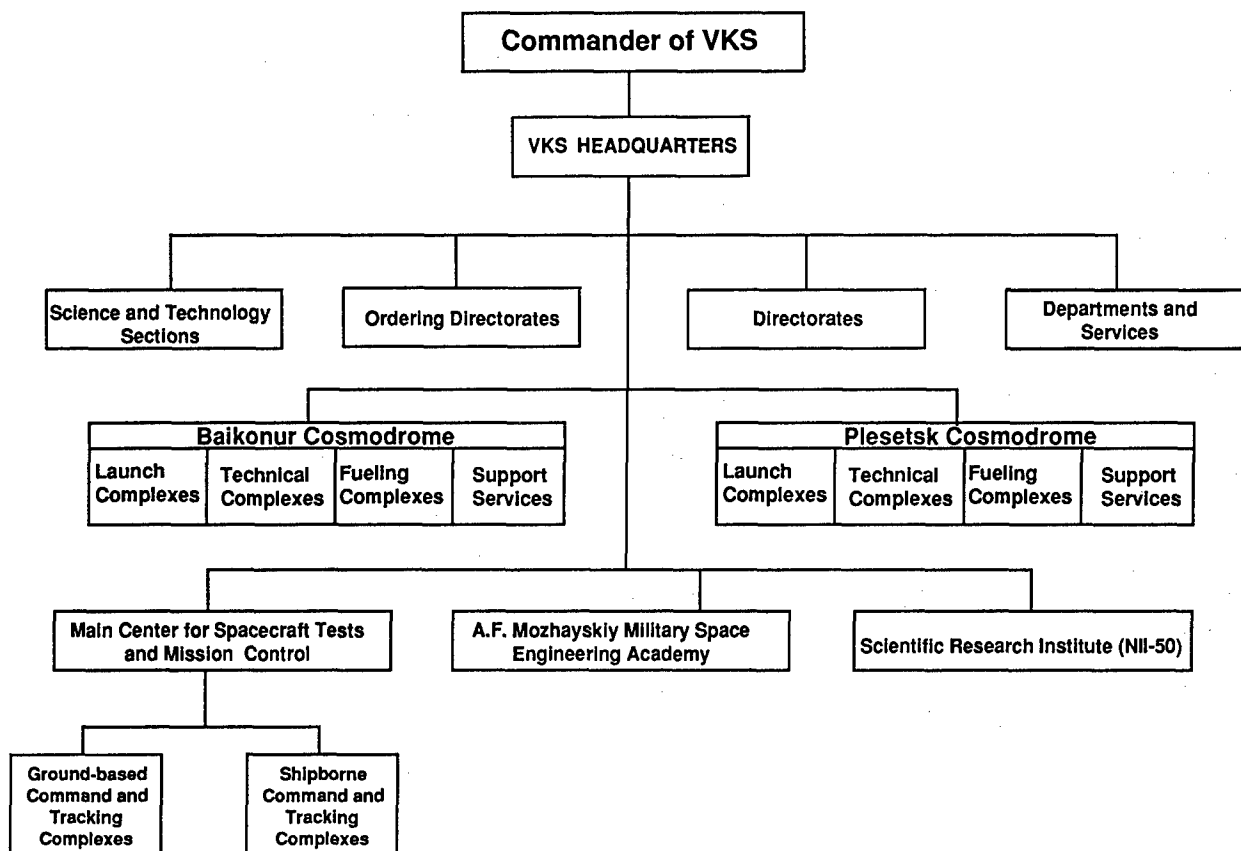


FIGURE 1.15 VKS ORGANIZATIONAL STRUCTURE.

scheduled for demolition in 1995, while the operational Dnepr radar nearby will remain open until 1998 under a Russian-Latvian agreement. A ninth sensor for the SSS is an ABM radar near Moscow. To augment the radar facilities which operate primarily at 150 MHz and 200 MHz, the SSS receives information from optical and electro-optical sites located in Russia, Kazakhstan, Tadjikistan, Ukraine, Georgia, Armenia, and Turkmenia. A unique facility on Mt. Maidanak in Uzbekistan also has space surveillance capabilities and is being examined by US officials for possible contributions to the tracking of very small objects in space. During 1993-1994 several SSS sensors were temporarily out of operation due to funding difficulties, including the inability to pay electrical bills to the now-commercial

power industry (References 86-90).

The Soviet aerospace industry was, by far, the largest of its kind in all of Europe and Asia. In the three years (1992-1994) following the demise of the USSR, the size and production capability of this enormous sector of the economy suffered significant reductions as government orders were sharply curtailed. From the largest manufacturers of satellites and launch vehicles to the smallest subsystem component vendor, the continuing breakdown in the entire military-industrial complex led to disruptions and even cancellations of planned activities. The severity of the situation caused the Russian Supreme Soviet to issue a decree on 27 April 1993 (Section 7.1) with the intent of stabilizing the increasing economic anarchy and the flight of professionals to other industries.

TABLE 1.3 MAJOR RUSSIAN INDUSTRIAL SPACE ORGANIZATIONS.

ORGANIZATION	LOCATION	SPECIALTIES
All-Russian Research Institute of Electromechanics	Moscow Region	Meteorological spacecraft, stabilization and solar array drive systems
Applied Mechanics Scientific Production Association	Krasnoyarsk	Communications, navigation, geodesy satellites
Arsenal Enterprise	St. Petersburg	Military space systems
Automation and Instrument Engineering Scientific Production Association	Moscow Region	Spacecraft guidance, navigation, control systems
Biofizpribor Specialized Design and Technological Bureau	St. Petersburg	Biological/physiological space flight equipment
Biotekhnika Scientific Production Association	Moscow Region	Biological/botanical space flight equipment
Central Aerohydrodynamics Institute	Moscow Region	Wind tunnels super/hypersonic modeling
Central Scientific Research Institute of Machine Building	Moscow Region	Space program administration, engineering, ballistics
Central Specialized Design Bureau	Samara	Manned and unmanned spacecraft, launch vehicles
Elas Scientific Production Joint-Stock Association	Moscow Region	Spacecraft electronics equipment
Elektronika Production Association	Voronezh	Electronic components
Energiya Rocket Space Corporation	Moscow Region	Manned/unmanned spacecraft and launch vehicles
Energomash Scientific Production Association	Moscow Region	Launch vehicle engines
Fakel Experimental Design Bureau	Moscow Region	Electric propulsion systems
General Machine Building Design Bureau	Moscow Region	Launch vehicle launch facilities
Gromov Flight Research Center	Moscow Region	Experimental aerospace vehicle testing
Institute of Biomedical Problems	Moscow Region	Biological (including human) spaceflight experiments
Institute of Physics and Power Engineering	Obninsk	Space power systems
Institute of Space Research	Moscow Region	Spacecraft scientific instruments
Instrument Building for Space Research NPO	Belgorod	Spacecraft subsystems
Isayev Chemical Engineering Design Bureau	Moscow Region	Spacecraft propulsion systems
Khimavtomatika Design Bureau	Voronezh	Launch vehicle engines
Khrunichev State Space Scientific Production Center	Moscow Region	Launch vehicles, manned spacecraft
Kometa Central Scientific Production Association	Moscow Region	Military space systems, large deployable antennas
Komplex Scientific and Technical Center	Moscow Region	Solid-propellant launch vehicles
Kompozit Joint-Stock Association	Moscow Region	Space technology materials
Kurchatov Institute of Atomic Energy	Moscow Region	Space nuclear power systems
Kvant State Scientific Production Enterprise	Moscow Region	Solar cells, storage batteries
Lavochkin Scientific Production Association	Moscow Region	Scientific instruments and spacecraft
LOMO Joint-Stock Association	St. Petersburg	Spacecraft optical, electro-optical equipment
Machine Building Scientific Production Association	Moscow Region	Remote sensing spacecraft
Makeyev Design Bureau and State Rocket Center	Chelyabinsk Region	Submarine-launch boosters and related payloads
Molniya Scientific Production Association	Moscow Region	Buran space shuttle, aerospace planes, aviation
Moscow Aviation Institute	Moscow Region	General aerospace design
Moscow Power Engineering Institute	Moscow Region	Ground control facilities
Precision Instruments Scientific Production Association	Moscow Region	Spacecraft control systems
Polet Aerospace Association	Omsk	Small spacecraft and launch vehicles
Russian Scientific Research Institute for Space Instrument Engineering	Moscow Region	Spacecraft equipment
Scientific Center Scientific Production Association	Moscow Region	Materials science, materials processing
Scientific Research Institute of Machine Building	Nizhnyaya Salda	Low thrust spacecraft engines
Scientific Research Institute of Thermal Processes	Moscow Region	Space nuclear power systems
Soyuz Scientific Production Association	Moscow Region	Spacecraft propulsion systems
Splav Technical Center	Moscow Region	Materials science, materials processing
Stekloplastik Scientific Production Association	Moscow Region	High technology materials
Tekhnologiya Scientific Production Association	Obninsk	High technology materials
Tekhnomash Scientific Production Association	Moscow Region	General aerospace technology
Trud Scientific Production Association	Samara	Aerospace engines
Vavilov State Optical Institute	St. Petersburg	Spacecraft optical, electro-optical equipment
Vega Scientific Production Association	Moscow Region	Radio and control systems
Vernadskiy Institute for Geochemistry and Analytical Chemistry	Moscow Region	Spacecraft scientific instruments
Vypel Corporation	Moscow Region	Space surveillance
Zvezda Scientific Production Association	Moscow Region	Life support systems

Conversion from government to commercial projects has been highly encouraged for almost all the major Russian space industries (Table 1.3). A 1993 goal was to consolidate and streamline the Russian space industry, creating four major space centers and 30-40 supporting enterprises from the existing >150 industries. A first step in this process came in June, 1993, when the Salyut Design Bureau and the Khrunichev Machine Building Plant were merged into the Khrunichev State Space Scientific Production Center. In February, 1994, Presidential Decree 237 enabled the government-owned Energiya NPO to begin privatization, although 51% of the ordinary shares were to be held by the government for at least three years. Another government decree two months later reinforced the Presidential decree and changed the name of the organization to the S.P. Korolev Energiya Rocket Space Corporation or RKK Energiya, for short. Also in 1994, several major space industries agreed to establish the Russian Aerospace Corporation and an Aerospace Bank (References 91-99).

The new Russian space law of 1993 (Section 7.3) specifically addressed the financing of space programs and foreign investments (Article 12) as well as establishing a space fund aimed primarily at supporting research and development activities (Article 13). However, both the 1993 and 1994 space budgets were approved only after torturous and protracted processes, during which skyrocketing inflation was diminishing the true

value. Figure 1.16 indicates the relative expenditures of the 1993 and the proposed 1994 space budgets, while Figure 1.17 denotes the programmatic breakdown for the 1993 budget. Of the 1,550 billion Rubles (1994 level) finally requested for the 1994 budget, 890 billion Rubles were appropriated and only 450 billion Rubles were actually funded. Scant information is available on the annual VKS budget, but requests for 1995 revealed planned expenditures essentially equal to that of the RKA. Both the RKA and the VKS provide funding for the Baikonur Cosmodrome in Kazakhstan. In June, 1994, the CIS Interstate Space Council adopted a program for 1994 calling for 1,200 billion Rubles, of which Moscow was expected to pay the lion's share (References 70, 100-105).

#### 1.10 UKRAINE

During the years of the USSR, Ukraine was the most important republic outside the Russian Federation contributing to the vast Soviet space program. The National Space Agency of Ukraine (NKAU) was formed on 2 March 1992, but, despite Ukraine's extensive space infrastructure and continuing support to the Russian Federation, the national space program has been slow to develop. By the end of 1994, Ukraine was anticipating the launch of its first domestic satellite and was rapidly forging bilateral and commercial agreements which could lead to a much stronger space program within the next few years.

The first Director General of NKAU, Volodymyr P. Gorbulin, was active in several top

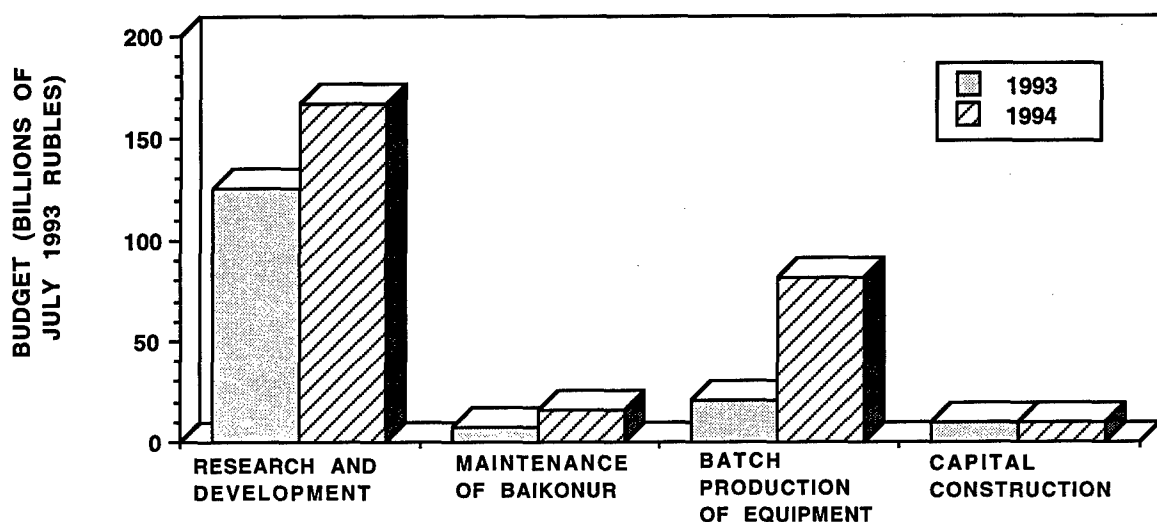


FIGURE 1.16 1993-1994 RKA SPACE BUDGETS.

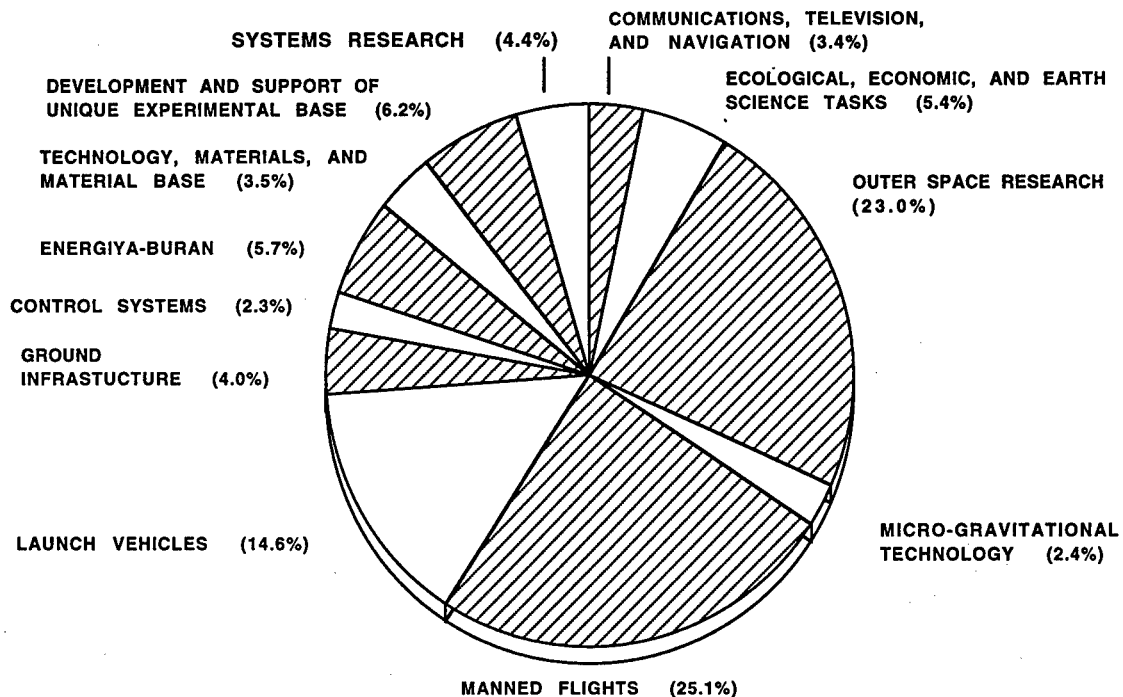


FIGURE 1.17 BREAKDOWN OF RKA 1993 SPACE BUDGET.

level government roles until his appointment as Secretary of the National Security Council in October, 1994. Consequently, the acting head of NKAU for much of 1994 was his deputy Andrei Zhalko-Tytarenko. Gorbulin, Zhalko-Tytarenko, and newly elected Ukrainian President Leonid Kuchma (July, 1994) all held senior management positions at the Yuzhnoye NPO in Dnepropetrovsk, the heart of Ukraine's space industry. Although a specific military space organization has not yet been created, movement in that direction has begun (References 106-111).

Ukraine's immediate plans are to launch an Earth observation satellite (Section 4.3.13) in 1995 and at least two communications satellites by the end of the decade. The Yuzhnoye NPO has already produced more than 400 Earth satellites dedicated to remote sensing, scientific, and national (USSR/CIS) security objectives. The firm is also the principal manufacturer of the Tsyklon and Zenit launch vehicles as well as the RS-20 ICBM which may soon see service as a space launch vehicle under the name SS-18K. Ukraine is also the home to the Yevpatoriya Deep Space Control Center, several TT&C facilities formerly belonging to the Soviet Ministry of Defense, and radar, optical, and electro-optical space surveillance complexes. The major space

infrastructure element missing is a space launch facility. In the near-term, Ukrainian boosters will be constrained to operations from the Russian Plesetsk Cosmodrome and the Kazakh-Russian Baikonur Cosmodrome, but alternatives, such as sea-based or new fixed foreign-based launches of Zenit are under active consideration.

Ukraine has sought to expand cooperative space programs not only with the Russian Federation but also with the US, India, Australia, and the International Space Station program. An agreement signed in 1994 with the US may lead to a Ukrainian cosmonaut on a STS mission in 1997, while another pact with India could result in the establishment of a Ukrainian-run Zenit launch facility in India. Zenit launchers have also been selected for support of the ISS, and space welding techniques developed by the Paton Institute of Electric Welding in Kiev are being considered by NASA for future construction projects in Earth orbit (References 112-118).

The principal centers of Ukrainian space industry are located in Dnepropetrovsk, Kiev, and Kharkov. Ukraine hopes to finance many of its proposed space programs through commercial ventures. The requested national space budget for 1993 was 36 million Ukrainian Rubles (Reference 119).

### 1.11 UNITED KINGDOM

During the 1960's the UK was an early and active participant in space activities, fielding its first national satellite in 1962 and conducting its first (and only) space launch in 1971. However, for a variety of reasons, support for space programs in the UK has waned steadily for the past two decades, and current funding is concentrated on Earth observation science and data processing. Since 1986 the UK has ranked fourth in its participation level within ESA and was the only ESA member to withhold support for both the Ariane 5 and the Hermes spaceplane projects.

The British National Space Center (BNSC) was established in 1985 as a coordinating agency among government departments and

research councils to help formulate and manage national space policy. The BNSC works directly with the Cabinet Office, the Ministry of Defense, the Meteorological Office, the Department of Trade and Industry, the Department of the Environment, the Foreign and Commonwealth Office, and the Department of Education and Science to this end (Figure 1.18). The title UK Space Minister falls within the portfolio of the Under-Secretary of State for Trade and Technology, a post which changed hands twice during 1993-1994 with Ian Taylor assuming the reigns in July, 1994. The Engineering and Physical Sciences Research Council and the Particle Physics and Astronomy Research Council were formed in 1994 from the former Science and Engineering Research

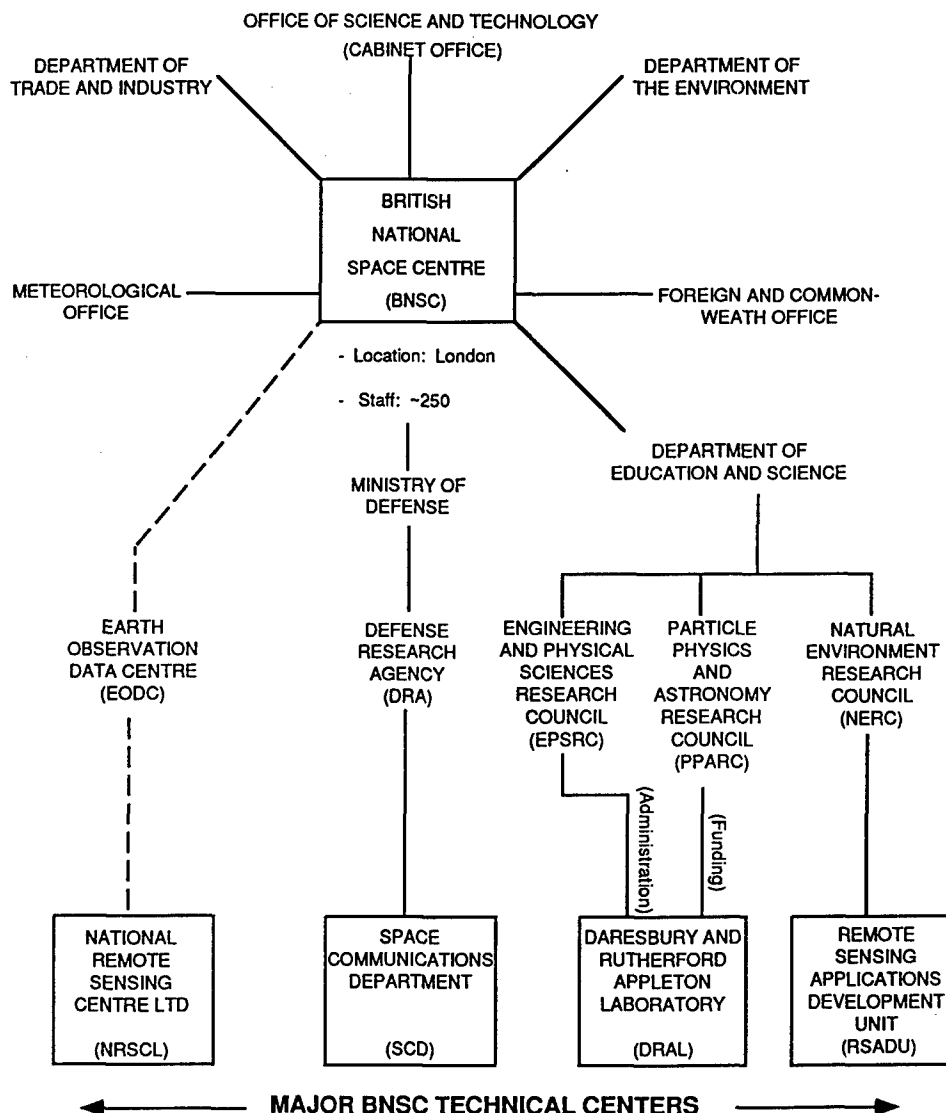


FIGURE 1.18 UK NATIONAL SPACE ORGANIZATIONAL STRUCTURE.



Council. Likewise, the Defense Research Agency's Space and Communications Department recently assumed the responsibilities of the Royal Aerospace Establishment and the Royal Signals and Radar Establishment for both civilian and military programs in the fields of space technology, mission analysis, and remote sensing.

With a staff of only approximately 250, BNSC primarily concentrates on advising government agencies and coordinating approved programs, with emphasis in Earth observation, satellite communications, technology and transportation, and space science. BNSC specifically supports programs which will

- help (Britain) understand our changing Earth,

- open up commercial and operational systems for the future,
- bring commercial returns, and
- support uniquely valuable space science" (Reference 120).

The founding Director General of BNSC, Arthur Pryor, was replaced in May, 1993, by Derek Davis. A reorganization of BNSC was completed the next year when the original four directorates were expanded into six: Earth Observations; Space Science; Technology; Industry and Exports; Satellite Communications, Applications, and Launchers; Policy, ESA, and European Union; and Finance. As indicated in Figure 1.18, four technical centers

are aligned with BNSC, including the recently created Daresbury and Rutherford Appleton Laboratory, which is the principal UK organization responsible for space science programs with ESA and bilateral partners.

The most significant aerospace firms in the UK have been British Aerospace and Matra Marconi Space UK. British Aerospace Space Systems Ltd. specialized in scientific spacecraft, communications, and satellite subsystems, while Matra Marconi Space UK, formed in 1990 along with Matra Marconi Space France during the merger of Matra Espace and Marconi Space Systems, is a complete space system and ground station design and manufacturing firm. In July, 1994, Matra Marconi Space acquired British Aerospace Space Systems Ltd. to create Europe's (then) leading space company and largest satellite manufacturer. A relative newcomer is Surrey Satellite Technology Limited of the University of Surrey which has already acquired an international reputation for the manufacture of miniature (<50 kg) satellites.

The annual (April through March) civilian space budgets for the UK were 171.31 million Pounds for 1993-1994 and 180.54 million Pounds for 1994-1995. Approximately two-thirds of this amount constitutes the UK donation to ESA. Figure 1.19 indicates the category breakdown for domestic and ESA expenditures for these two fiscal years.

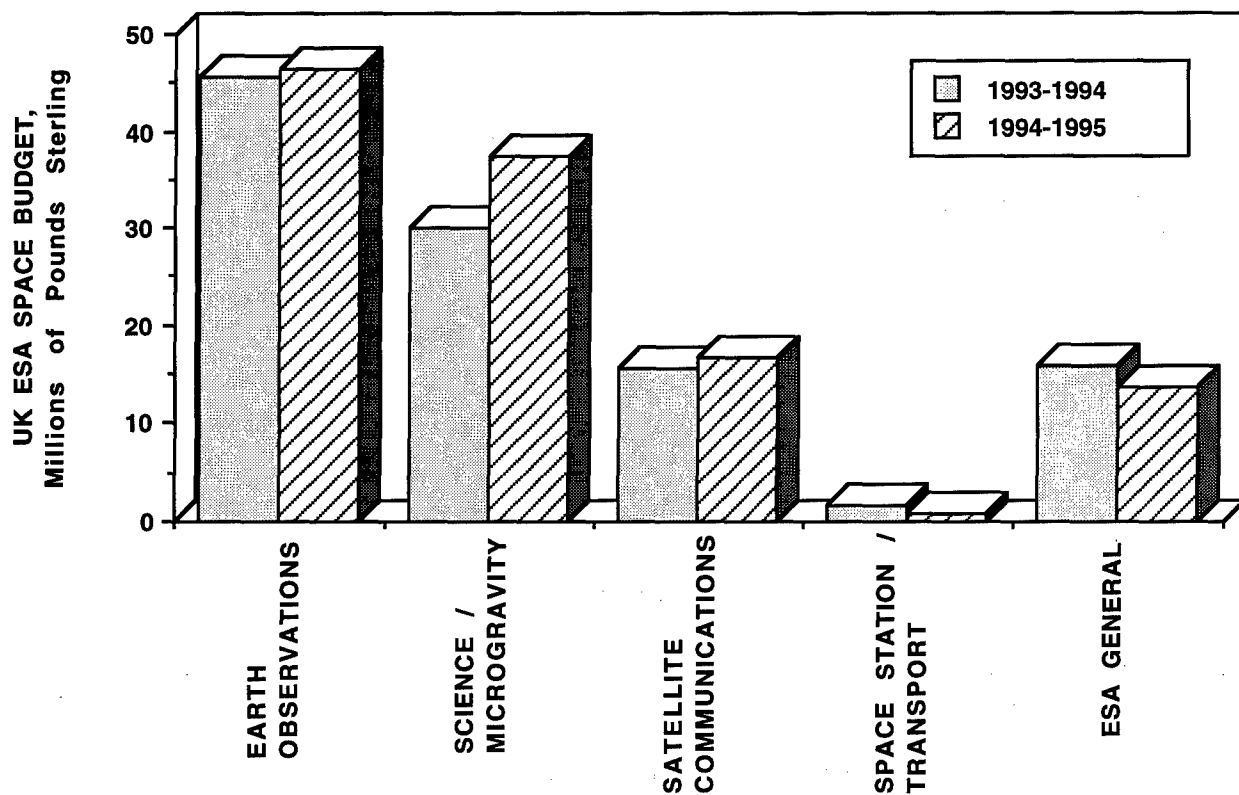
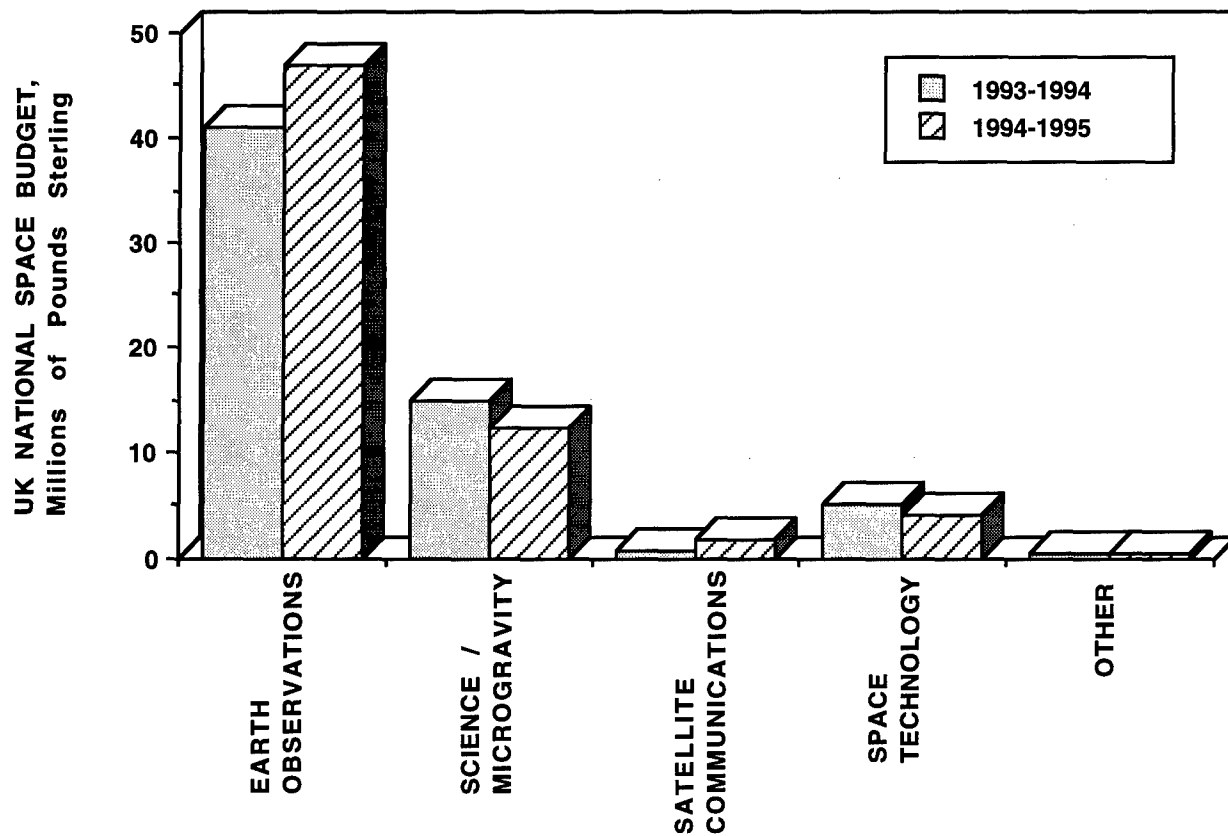


FIGURE 1.19 1993-1994 UK SPACE BUDGETS.

## References - Section 1

1. ESA Convention, entered into force in 1980.
2. ESOC. The European Operations Centre, ESA f-15, ESA, September 1988.
3. Annual Report '94, ESA, 1995, pp. 77-81, 95-97.
4. To Last a Lifetime. The ESTEC Test Centre, ESA F-25, ESA, June 1990.
5. Making Sure - A Brief Outline and History of ESA's Test and Checkout Services, ESA BR-22, ESA, 1984.
6. Touchstone for Success, ESA BR-52, ESA, July 1988.
7. Annual Report '94, op. cit., pp. 92-95.
8. ESRIN, ESA br-58, ESA, 1989.
9. "The Nerve Center of Europe in Space: ESRIN", ESA Features, No. 19, 11 April 1991.
10. All About the European Space Agency, ESA, May 1995, p. 3.
11. Annual Report '94, op. cit., pp. 98-101.
12. Annual Report '93, ESA, 1994, pp. 92-94.
13. A. Ripoll, et al, "The New European Astronauts Centre", ESA Bulletin, No. 64.
14. Annual Report, ESA, 1992, pp. 12-14; 1993, pp. 10-12; 1994, pp. 12-14.
15. P.B. de Selding, "ESA Seeks To End Differences Over Exchange Rates", Space News, 31 January - 6 February 1994, p. 11.
16. A Lightning Tour Through CNES, CNES, Paris, 1992.
17. C. Lardier, "12,1 Milliards F (+1%) Pour Le CNES En 1995", Air & Cosmos, 14 April 1995, p. 35.
18. P.B. de Selding, "French Up Military Spending", Space News, 10-16 October 1994, pp. 1, 20.
19. Raumfahrt-fur die Erde ins All, DARA, Geschäftsbericht, 1993.
20. A Look At the Future, DLR, Cologne-Porz, April 1991.
21. D. Mehrholz, "Space Object Observation with Radar", Paper B.8-M.1.03, World Space Congress, August-September 1992.
22. P.B. de Selding, "DARA Slices Staff, Resources Due to Sluggish Economy", Space News, 7-13 March 1993, p. 14.

23. G. de Briganti, "Germany Poised To Bankroll Military Space", Space News, 17-23 October 1994, pp. 1, 20.
24. G.D. Ojalehto and H.R. Hertzefeld, "Nations Aim High Despite Falling Budgets", Aerospace America, July 1995, pp. 4-7, 40-41.
25. J. Fairall, "India's Global Aims", Space, January-February 1995, pp. 17-18.
26. "Newsmaker Forum", Space News, 20-26 February 1995, p. 22.
27. L. David, "India's Space Program Picks Up the Pace", Aerospace America, August 1995, pp. 32-35, 45.
28. Annual Report 1988-89, Department of Space, 1989.
29. A. Lawler, "ISRO Purchases Intended To Boost Commercial Space", Space News, 11-17 May 1992, p. 14.
30. V. Raghuvanshi, "India's Antrix Corp. Targets Technology Export Market", Space News, 14-20 December 1992, p. 25.
31. S. Fisher, "Israel Joins Up", Space, January-February 1991, pp. 12-14.
32. J. Simpson et al, "The Israeli Satellite Launch", Space Policy, May 1989, pp. 117-128.
33. C. Meyer, "Credits En Hausse Pour L'Espace Israelien", Air & Cosmos, 4 November 1994, p. 38.
34. M. Williamson, "The AMOS Technology Leap", Space, January-February 1995, pp. 19-21.
35. T. Pirard, "Israel Invests in Space Technology", Spaceflight, April 1995, p. 121.
36. P.B. de Selding, "ISA Petitions for Boost in Budget", Space News, 17-23 October 1993, p. 8.
37. R. Riccitiello, "Colombo To Head Italian Ministry", Space News, 17-23 May 1993, p. 14.
38. R. Riccitiello, "Buongiorno Eager To End Tenure as ASI Chief", Space News, 10-16 May 1993, pp. 4, 21.
39. "Italian Minister Plans New Leadership at ASI", Space News, 2-8 August 1993, p. 2.
40. P.B. de Selding, "Italians Pick Puppi To Be ASI's Interim Chief", Space News, 6-12 September 1993, p. 4.
41. S. Coledan, "Italy Charges ASI With Fund Misuse", Space News, 15-28 November 1993, pp. 1, 28.
42. R. Riccitiello, "Minister: No Criminality Found in ASI Probe", Space News, 28 February - 6 March 1994, p. 6.
43. "Fiocco Chosen To Lead Italian Space Agency", Space Agency, 28 February - 6 March 1994, p. 2.
44. S. Coledan, "Italy's Government Gives ASI New Boss", Space News, 10-16 October 1994, pp. 3, 21.
45. E. Battifoglia, "Italy Looks Forward", Space, November-December 1994, p. 21.

46. R. Riccitiello, "Italy Seeks To Increase Presence in ESA Hierarchy", Space News, 22 June - 5 July 1992, p. 21.
47. P.B. de Selding, "Italy Pares Financial Commitment to ESA Programs", Space News, 1-7 November 1993, p. 16.
48. P.B. de Selding, "ESA Loan Will Ease Italy's Dilemma", Space News, 21-27 February 1994, pp. 4, 21.
49. "Italy Space Agency Gets OK To Pay Dues", Space News, 30 May - 12 June 1994, p. 2.
50. S. Saito, "Japan's Space Policy", Space Policy, August 1989, pp. 193-200.
51. S. Kurachi, "Update on Japan's Space Policy", Space Policy, May 1991, pp. 95-102.
52. NASDA. National Space Development Agency of Japan, NASDA, 1994.
53. M. Oda and Y. Tanaka, "Japan's Blossoming Space Science", Sky and Telescope, January 1987, pp. 7-11.
54. "Newsmaker Forum", Space News, 27 July-9 August 1992, p. 30.
55. N. W. Davis, "Japan's ISAS Pursues 'Independent' Agenda", Aerospace America, July 1993, pp. 13-15.
56. The Institute of Space and Astronautical Science. 1993, Ministry of Education, Science, and Culture, 1993.
57. NAL 1993-1994, NAL, 1994.
58. NAL Research Progress 1993, NAL, 1994.
59. NAL Research Progress 1994, NAL, 1995.
60. Space in China. Launch Services and Space Technology, CGWIC, 1992.
61. Xinhua News Agency, 21 May and 8 July 1993.
62. Reuter (Beijing), 7 June 1993.
63. A. Lawler, "China Pushes For Satellite Export Work", Space News, 19-25 July 1993, pp. 1, 28.
64. "Newsmaker Forum", Space News, 14-20 February 1994, p. 22.
65. A. Lawler, "China Lifts Veil of Secrecy From Its Space Budget", Space News, 28 February - 6 March 1994, pp. 3, 21.
66. A. Lawler, "Chinese Facing Financial Crunch", Space News, 7-13 March 1994, pp. 4, 29.
67. Y. Koptev, "On Russia's Space Effort in the Period of Up to the Year 2000", Aviation & Space News, Vol. 1, No. 1, 1993, pp. 5-11.

68. Y.G. Milov, "The Basic Elements of Russia's Space Program", Space Bulletin, Vol. 1, No. 2, 1993, pp. 2-7.
69. S. Leskov, Izvestiya, 13 February 1993, p. 15.
70. Space Policy & Industry in CIS Countries, Vol. 1, Space Industries and Markets in Russia and Other Countries of the Former Soviet Union, Euroconsult, October 1993.
71. V.V. Alaverdov, et al, Zemlya i Vselennaya, September-October 1993, pp. 3-11.
72. S. Yermak and V. Men'shikov, Aviatsiya i Kosmonavtika, September-October 1993, pp. 2-3.
73. M. Chernyshov, Segodnya, 5 October 1994, p. 9.
74. Ostankino Television, 9 October 1994.
75. D. Makrov, Argumenty i Fakty, April 1993.
76. Aviatsiya i Kosmonavtika, April 1993, pp. 6-7.
77. V. Baberdin, Vozdushnyy Transport, September 1993, p. 6.
78. Russia Television, 1 August 1993.
79. M. Rebrov, Krasnaya Zvezda, 16 August 1995.
80. V.L. Ivanov, Osnovnyye Vekhi Kosmicheskoy Ery, 1993.
81. V. Makashin, Krasnaya Zvezda, 6 December 1994, p. 1.
82. NTV, 22 and 23 July 1994.
83. F. Mishin, "Tracking and Data Acquisition Network", Man & Space, Vol. 1, No. 1, 1992, pp. 41-43.
84. V. Baberdin, Krasnaya Zvezda, 9 October 1993, p. 2.
85. V. Baberdin, Krasnaya Zvezda, 21 April 1992, p. 2 and 22 April 1992, p. 2.
86. G. Batyr, et al, "The Current State of Russian Space Surveillance System and its Capability in Surveying Space Debris", Proceedings of the First European Conference on Space Debris, ESA SD-01, 1993, pp. 43-47.
87. J. Trops, DIENA (Riga), 3 November 1994, p. 3.
88. Moscow Russian Television Network, 3 May 1995.
89. W.B. Scott, "Russian Politics May Stymie Laser/Optics Collaboration", Aviation Week and Space Technology, 21 March 1994, pp. 49-50.

90. W.B. Scott, "Uzbek Site May Benefit U.S. Surveillance Network", Aviation Week and Space Technology, 15 May 1995, pp. 68-69.
91. Interfax News Agency, 8 June 1993.
92. S. Golotyuk, Moscow News, 2 July 1993, p. 9.
93. I. Matreyeva, Kommersant Deyli, 31 May 1994, p. 9.
94. C. Covault, "95,000 Russian Layoffs, Launch Breakdown Feared", Aviation Week and Space Technology, 15 November 1993, p. 27.
95. J.M. Lenorovitz, "Energiya Wins Approval For Privatization", Aviation Week and Space Technology, 27 June 1994, pp. 22-23.
96. "RKK Energia Issues Stock Due to Privatization Order", Space News, 17-23 October 1994, p. 11.
97. U.S.-Russian Cooperation in Space, Office of Technology Assessment, US Congress, April 1995.
98. The Russian Space Directory 1994, European Space Report, 1993.
99. Directory of Russian Space Industry, 1994-1995, Sevig Press, 1994.
100. B. Ostroumov, Trud, 10 December 1994, p. 2.
101. P. Yevseyev, Finansovyye Izvestiya, 18-24 August 1994, p. 4.
102. ITAR-TASS News Agency, 12 May 1994.
103. V. Khalin, Delovoy Mir, 30 April 1994, p. 5.
104. D. Payson, Nezavisimaya Gazeta, 14 January 1994, pp. 1-2.
105. A. Lawler, "Financial Woes May Cripple Russian Space", Space News, 1-7 August 1994, pp. 1, 20.
106. Pravda Ukrainy, 11 April 1992, p. 2.
107. Demokratychna Ukrayina, 11 April 1992, p. 1-2.
108. G. Klyuchikov, Narodnaya Armiya, 10 April 1993, pp. 1-2.
109. UNIAN News Agency, 3 September 1993.
110. S. Zgurets, Narodnaya Armiya, 15 December 1993, p. 3.
111. V. Pikhovshek, Most, 1-7 May 1995, pp. 3-5.

112. T. Hitchens and A. Lawler, "U.S. Offers Ukraine Space Cooperation", Space News, 8-14 August 1994, pp. 3, 20.
113. P. Mann, "U.S., Ukraine Sign Space Pact", Aviation Week and Space Technology, 28 November 1994, pp. 26-27.
114. Interfax News Agency, 20 September 1994.
115. "Space Welding Tool", Spaceflight, February 1995, p. 68.
116. "Ukrainian Space Tool To Be Tested on Shuttle", Space News, 5-11 June 1995, p. 14.
117. UKRINFORM, 17 January 1995.
118. P. Beba and A. Chryva, Uryadovyy Kuryer, 4 March 1995, p. 7.
119. Vecherniy Kiyev, 10 April 1993, pp. 1, 4.
120. UK Space Activities 1993-1994, BNSC, 1993, p. 4.



## 2.0 SPACE TRANSPORTATION SYSTEMS AND LAUNCH FACILITIES

Of the 176 world-wide space launches undertaken during the 1993-1994 period, 124 (70.5%) were conducted by the European and Asian space powers from eight space centers around the world (Figure 2.1). Each of the five major space-faring organizations and nations posted gains in 1994 over the previous year's activities with the CIS accounting for 78% of all launches (Figure 2.2). Moreover, the aggregate reliability of these diverse space transportation systems was greater than 95%, essentially the same reliability demonstrated by 29 different launch vehicle models flown during the first half of the 1990's (Table 2.1).

With payload capacities ranging from 150 kg to more than 21,000 kg, these expendable launch vehicles serve national space support needs as well as provide commercial launch services to the entire world. To meet growing space transportation requirements, five new launch vehicles debuted during 1993-1994: two from the Russian Federation and one each from ESA, India and the PRC. By the end of the decade, more than ten new launch vehicles

may be added to this arsenal with capabilities for ground, sea, or air launches. Earlier predictions for a significant expansion in the club of space launching nations have recently been tempered with technical, economic, and market realities.

For the remainder of this decade, the principal Eurasian entries into the global commercial space transportation competition will be the Russian Proton, ESA's Ariane, and the Chinese Long March (CZ) family of launch vehicles. Figure 2.3 indicates the levels of activity and cumulative reliability for these systems during the seven-year 1988-1994 period. A summary of Eurasian liquid rocket engine technology, some of which may find its way into the US launch vehicle industry, is found in Table 2.2. Additional details are provided in the following subsections.

### 2.1 EUROPEAN SPACE AGENCY

ESA introduced the European-built Ariane launch vehicle in 1979, and by the end of 1994 the organization had conducted 70 missions,

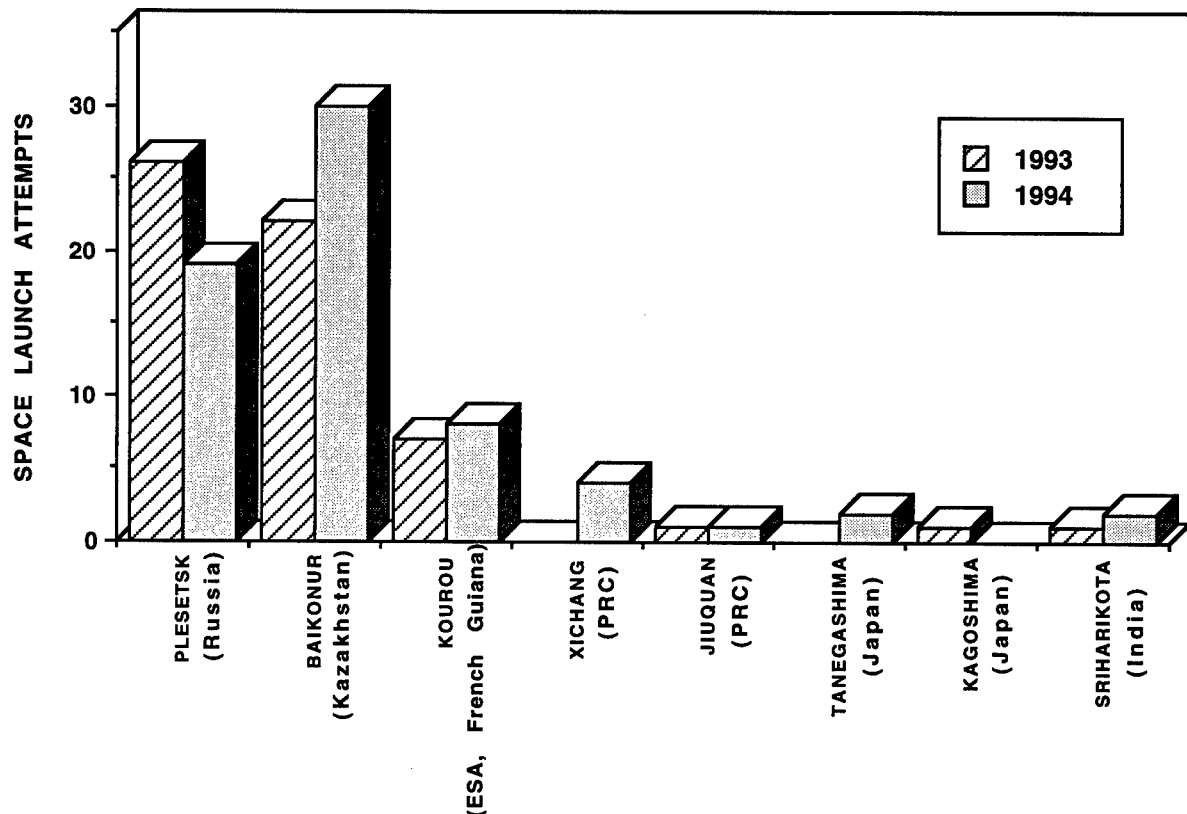


FIGURE 2.1 EURASIAN SPACE LAUNCH SITE ACTIVITY, 1993-1994.

TABLE 2.1 EUROPEAN AND ASIAN SPACE LAUNCH VEHICLES, 1990-1994.

COUNTRY / ORG.	LAUNCH VEHICLE	MISSIONS	FAILURES	RELIABILITY (%)
CIS/USSR	KOSMOS-3M	40	1	97.5
	MOLNIYA-M	36	1	97.2
	PROTON-K (3)	2	0	100
	PROTON-K (4)	45	2	95.6
	ROKOT	1	0	100
	SOYUZ-U/U2	112	3	97.3
	START-1	1	0	100
	TSYKLON-2	10	0	100
	TSYKLON-3	32	1	96.9
	VOSTOK*	1	0	100
	ZENIT-2	12	3	75
	<b>TOTAL</b>	<b>292</b>	<b>11</b>	<b>96.2</b>
ESA	ARIANE-40	3	0	100
	ARIANE-42P	7	1	85.7
	ARIANE-42L	2	0	100
	ARIANE-44P	2	0	100
	ARIANE-44L	14	1	92.9
	ARIANE-44LP	8	1	87.5
	<b>TOTAL</b>	<b>36</b>	<b>3</b>	<b>91.7</b>
JAPAN	H-I*	4	0	100
	H-II	2	0	100
	M-3SII	3	0	100
	<b>TOTAL</b>	<b>9</b>	<b>0</b>	<b>100</b>
INDIA	ASLV	2	1	50
	PLSV	2	1	50
	<b>TOTAL</b>	<b>4</b>	<b>2</b>	<b>50</b>
ISRAEL	SHAVIT	1	0	100
	<b>TOTAL</b>	<b>1</b>	<b>0</b>	<b>100</b>
PRC	CZ-2C	3	0	100
	CZ-2D	2	0	100
	CZ-2E	4	1	75
	CZ-3	4	1	75
	CZ-3A	2	0	100
	CZ-4	1	0	100
	<b>TOTAL</b>	<b>16</b>	<b>2</b>	<b>87.5</b>

Failure: Launch vehicle did not deliver payload to the intended orbit and release properly

\* : No longer in use

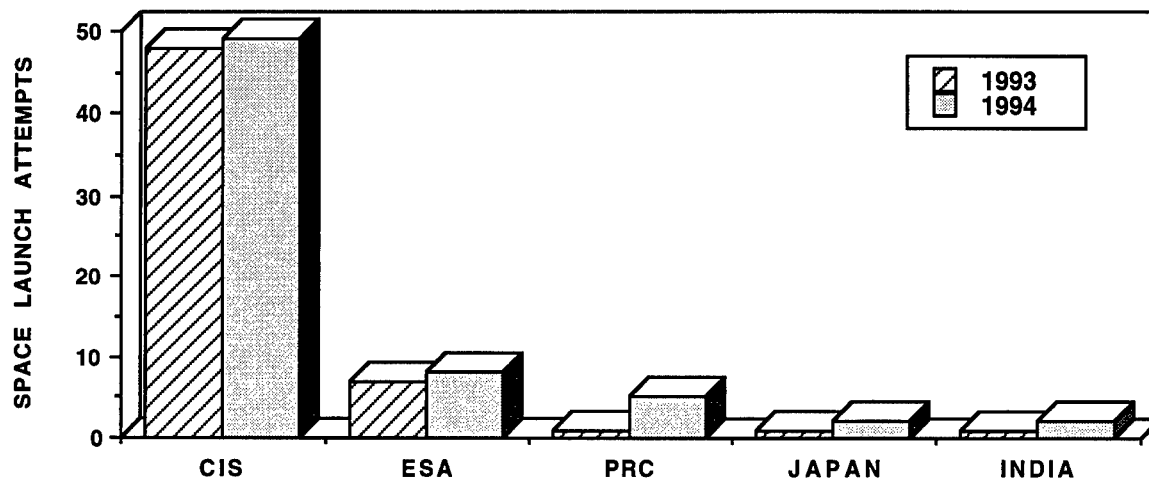


FIGURE 2.2 EURASIAN SPACE LAUNCH HISTORY, 1993-1994.

almost all for purely commercial purposes, with an overall success record of 90.0% (Figure 2.4). The original Ariane 1 vehicle was joined in 1984 by Ariane 2/3 and in 1988 by Ariane 4. Since 1989 all ESA orbital flights have used a variant of the Ariane 4 booster. In 42 launches Ariane 4 suffered three failures for a 92.9% reliability mark, but two of these losses occurred in 1994. The substantially larger Ariane 5 launch vehicle is scheduled to debut in early 1996.

The basic Ariane 4, also known as the Ariane 40 variant, is a three-stage, liquid propellant booster with a 1.9-metric-ton payload capacity to a 7°-inclined GTO or 2.7 metric tons to an 800-km, sun-synchronous orbit. The first stage (L220) is powered by four Viking 5C engines burning nitrogen tetroxide and a combination of UDMH plus hydrazine hydrate called

UH25. The second stage (L33) employs the same propellants with a single, higher thrust Viking 4B engine. The third stage (H10 or H10 Plus) burns liquid oxygen and liquid hydrogen through an HM-7B engine (References 1-4).

The Ariane 4 program is managed and launch services are marketed by Arianespace, while the French space agency CNES is responsible for overall design and serves as general contractor. The primary industrial agent and integration contractor for stages one and three is Aerospatiale. Germany's DASA is the prime contractor for stage 2. Main engines are provided by SEP. In all, more than three dozen European companies provide significant services in the design, manufacture, and operation of the Ariane 4.

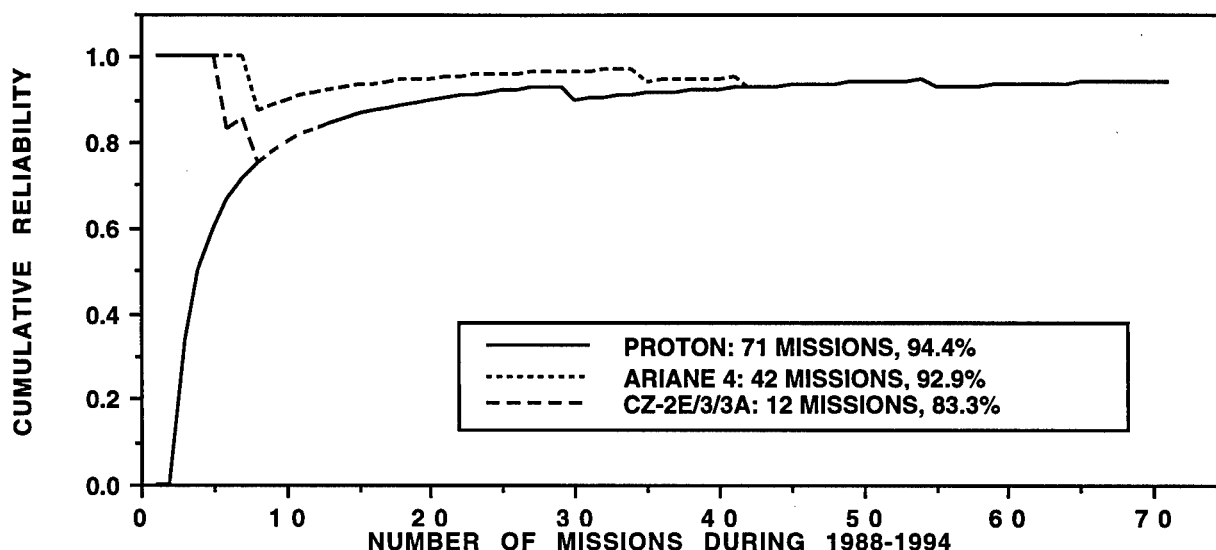


FIGURE 2.3 CUMULATIVE RELIABILITY OF COMMERCIAL LAUNCH VEHICLES.

TABLE 2.2 MAJOR LIQUID-PROPELLANT LAUNCH VEHICLE MAIN ENGINES.

COUNTRY/ ORGANIZATION	ENGINE DESIGNATOR	LAUNCH VEHICLE	STAGE	NO. OF ENGINES PER STAGE	FUEL	OXIDIZER	MAXIMUM THRUST (kN)	SPECIFIC IMPULSE (sec)
ESA	HM-7B	Ariane 4	3rd	1	LH	LOX	62 (vac)	444 (vac)
	Vulcain	Ariane 5	1st	1	LH	LOX	800 (sl)	>400 (sl)
	Viking 4B	Ariane 4	2nd	1	UH25	NTO	786 (vac)	297 (vac)
	Viking 5C	Ariane 4	1st	4	UH25	NTO	677 (sl)	249 (sl)
	Viking 6	Ariane 4	Strap-on	1 ea.	UH25	NTO	667 (sl)	248 (sl)
	Aestus	Ariane 5	2nd	1	MMH	NTO	28 (vac)	322 (vac)
INDIA	Vikas	PSLV	2nd	1	UDMH	NTO	725 (vac)	293 (vac)
	GSLV		Strap-on, 2nd	1 ea.				
	unk	PSLV	4th	1	MMH	NTO	7.5 (vac)	308 (vac)
JAPAN	LE-5A	H-II	2nd	1	LH	LOX	122 (vac)	452 (vac)
	LE-7	H-II	1st	1	LH	LOX	843 (sl)	>400 (sl)
PRC	YF-20	CZ-2C	1st	4	UDMH	NTO	697 (sl)	259 (sl)
		CZ-3	1st	4				
	YF-20B	CZ-2D	1st	4	UDMH	NTO	741 (sl)	261 (sl)
		CZ-2E	Strap-on, 1st	4 ea.				
		CZ-3A	1st	4				
		CZ-4	1st	4				
	YF-22	CZ-2C	2nd	1	UDMH	NTO	720 (vac)	289 (vac)
		CZ-3	2nd	1				
	YF-22B	CZ-2D	2nd	1	UDMH	NTO	741 (vac)	298 (vac)
		CZ-2E	2nd	1				
		CZ-3A	2nd	1				
		CZ-4	2nd	1				
	YF-40	CZ-4	3rd	1	UDMH	NTO	49 (vac)	305 (vac)
	YF-73	CZ-3	3rd	1	LH	LOX	44 (vac)	420 (vac)
	YF-75	CZ-3A	3rd	2	LH	LOX	79 (vac)	442 (vac)

LH: Liquid Hydrogen

LOX: Liquid Oxygen

MMH: Monomethylhydrazine

NTO: Nitrogen Tetroxide

UDMH: Unsymmetrical Dimethylhydrazine

UH25: UDMH + 25% hydrazine hydrate

sl: sea level

vac: vacuum

TABLE 2.2 MAJOR LIQUID-PROPELLANT LAUNCH VEHICLE MAIN ENGINES (continued).

COUNTRY/ ORGANIZATION	MAIN ENGINE UNIT DESIGNATOR(S)	LAUNCH VEHICLE	STAGE/BLOCK	NO. OF ENGINES PER STAGE/BLOCK	FUEL	OXIDIZER	MAXIMUM THRUST (kN)*	SPECIFIC IMPULSE (sec)*
RUSSIAN FEDERATION	D-57	TBD	TBD	TBD	LH	LOX	392 (vac)	457 (vac)
	KVD-7.5	Proton-KM GSLV	4th/D 3rd	1	LH	LOX	76 (vac)	461 (vac)
	NK-33	TBD	1st/A	TBD	Kerosene	LOX	1510 (sl)	297 (sl)
	RD-58M/11D58M	Proton-K	4th/D	1	Kerosene	LOX	85 (vac)	354 (vac)
	RD-107/11D511	Soyuz-U	1st/B,V,G,D	1	Kerosene	LOX	821 (sl)	254 (sl)
	RD-107/8D728	Molniya-M	1st/B,V,G,D	1	Kerosene	LOX	828 (sl)	257 (sl)
	RD-108/11D512	Soyuz-U	1st/A	1	Kerosene	LOX	746 (sl)	250 (sl)
	RD-108/8D727	Molniya-M	1st/A	1	Kerosene	LOX	744 (sl)	248 (sl)
	RD-120/11D123	Zenit	2nd/B	1	Kerosene	LOX	835 (vac)	352 (vac)
	RD-120K	TBD	TBD	TBD	Kerosene	LOX	850 (vac)	331 (vac)
	RD-161	TBD	TBD	TBD	Kerosene	LOX	20 (vac)	365 (vac)
	RD-170/11D520	Energiya	1st/A(4)	1	Kerosene	LOX	7261 (sl)	309 (sl)
	RD-171/11D521	Zenit	1st/A	1	Kerosene	LOX	7261 (sl)	309 (sl)
	RD-180	TBD	1st/A	TBD	Kerosene	LOX	3685 (sl)	308 (sl)
	RD-216/11D614	Kosmos-3M	1st/A	2	UDMH	NTO/NA	742 (sl)	251 (sl)
	RD-218/11D69	Tsyklon	1st/A	3	UDMH	NTO	740 (sl)	246 (sl)
	RD-219/11D26	Tsyklon	2nd/B	1	UDMH	NTO	882 (vac)	324 (vac)
	RD-253/11D48	Proton-K	1st/A	6	UDMH	NTO	1473 (sl)	285 (sl)
	RD-704	TBD	TBD	TBD	Kerosene/LH	LOX	4000 (vac)	415/460 (vac)
	RD-0110/11D55	Soyuz-U Molniya-M	2nd/B 2nd/B	1 1	Kerosene	LOX	300 (vac)	332 (sl)
	RD-0120/11D122	Energiya	1st/Ts	4	LH	LOX	1960 (vac)	455 (vac)
	RD-0210/8D411K	Proton-K	2nd/B	3	UDMH	NTO	594 (vac)	333 (vac)
	RD-0211/8D412K	Proton-K	2nd/B	1	UDMH	NTO	594 (vac)	333 (vac)
	RD-0212/8D48	Proton-K	3rd/V	1	UDMH	NTO	594 (vac)	330 (vac)
	RD-2/11D49	Kosmos-3M	2nd/B	1	UDMH	NTO	157 (vac)	303 (vac)
	RD-2/11D33	Molniya-M	3rd/L	1	Kerosene	LOX	68 (vac)	347 (vac)
UKRAINE	RD-861/11D25	Tsyklon	3rd/V	1	UDMH	NTO	78 (vac)	323 (vac)

LH: Liquid Hydrogen  
LOX: Liquid Oxygen  
NA: Nitric Acid

NTO: Nitrogen Tetroxide  
UDMH: Unsymmetrical Dimethylhydrazine

sl: sea level  
vac: vacuum

\* Values may vary a few percent depending upon engine version

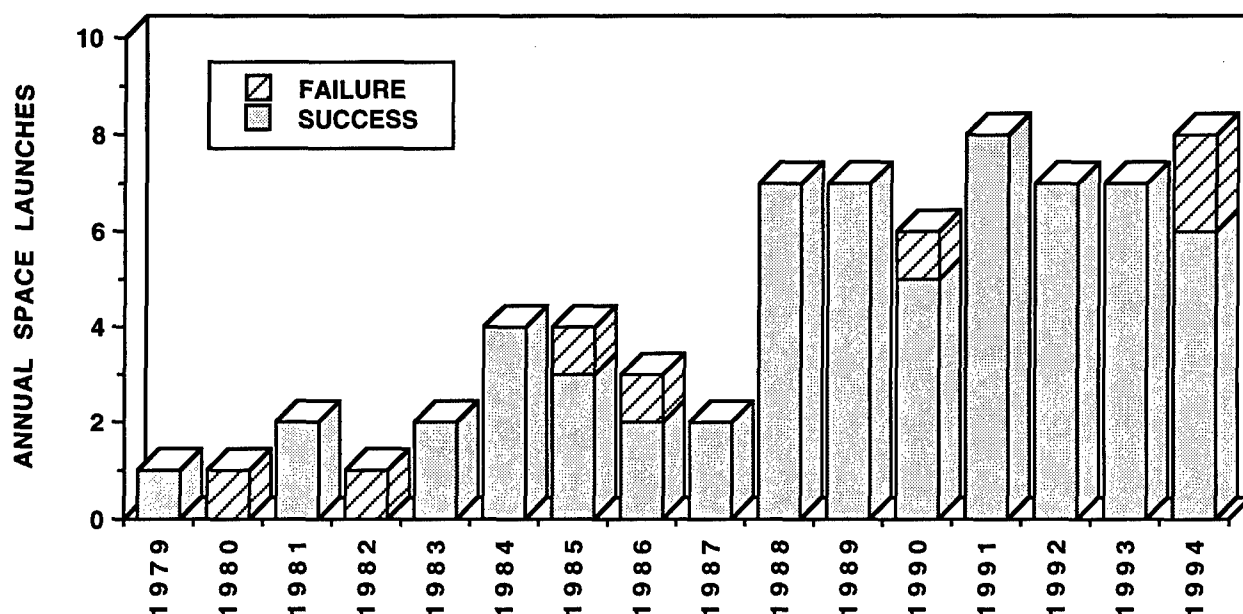


FIGURE 2.4 ARIANE LAUNCH VEHICLE FLIGHT RECORD.

The Ariane 40 variant has actually only flown three times to place payloads into low altitude, sun-synchronous orbits (1990, 1991 and 1993). Since the principal mission of Ariane 4 is to insert commercial satellites into GTO, five other booster variants are available depending upon the mass of the payload and whether one or two main satellites are to be carried. The five variants are distinguished by the number and type (liquid propellant or solid propellant) of the small boosters attached to the first stage. The original GTO payload capacity ranged from 2.6 metric tons for two solid boosters (PAP, Propulseur d'Appoint Poudre) to 4.2 metric tons for four liquid boosters (PAL, Propulseur d'Appoint Liquide) (Figure 2.5). The most widely used variant is the most powerful Ariane 44L, and by the end of 1993 all the variants had flown at least once. During the 1990's upgrades (lengthening of the third stage and a new propellant management technique) increased the lifting power of Ariane 4, bringing the Ariane 44L capacity up to 4.7 metric tons (References 5-7). The major contractor for the PAL, which employs the same propellants as the first two stages and a Viking 6 engine, is DASA/ERNO, whereas SNIA/BPD is in charge of the PAP.

To permit the launching of two large, independent spacecraft on a single booster, one satellite is encased in a special housing SYLDA or SPELDA (Système de Lancement Double Ariane or Structure Porteuse pour Lancements

Double Ariane), while the second satellite is mounted on top of the housing. Both the housing and the upper satellite are then covered by the payload shroud which is jettisoned at an altitude of about 115 km. Once the Ariane third stage reaches GTO, the upper satellite is released, followed by separation of the top portion of the SYLDA or SPELDA and release of the second satellite. Injection into GEO is the responsibility of the individual satellites. For the infrequent LEO missions, a multiple payload platform called ASAP (Ariane Structure for Auxiliary Payloads) can carry up to six small (less than 50 kg) piggyback satellites without interfering with the primary payload.

A total of 15 Ariane launches were conducted during 1993-1994 (the same as the 1991-1992 period) carrying 31 individual spacecraft, only one of which was sponsored by ESA (Section 8). Unfortunately, the flights of missions 63 and 70 (January and December 1994) both failed to reach Earth orbit due to malfunctions in the cryogenic third stage. An accident investigation for flight 63 found the principal cause of failure to be overheating of the LOX turbopump bearing, which had already been identified as a deficiency and was scheduled for correction by flight 70 (References 8-10). By April, 1994, a redesigned third stage engine was delivered to Aerospatiale, and flight operations resumed in June. However, after six successful Ariane flights in as many months, flight 70 failed to reach Earth

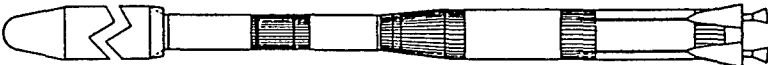
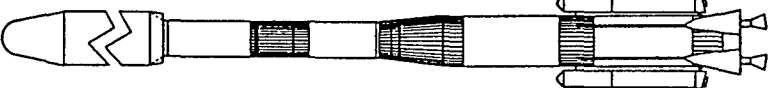
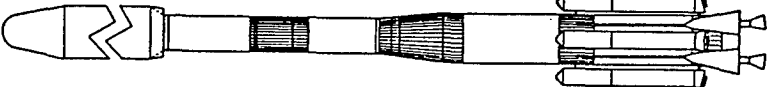



						
NAME	ARIANE 40	ARIANE 42P	ARIANE 44P	ARIANE 42L	ARIANE 44LP	ARIANE 44L
FLIGHT OF ORIGINAL MODEL	1990	1990	1991	1993	1988	1989
ORIGINAL GTO PAYLOAD (KG)	1900	2600	3000	3200	3700	4200
CURRENT GTO PAYLOAD (KG)	2070	2920	3380	3450	4170	4700
1993 SPACE MISSIONS	1	1	0	1	2	2
1994 SPACE MISSIONS	0	2	0	1	3	2
1988-1994 SPACE MISSIONS	3	7	2	2	12	16
1988-1994 RELIABILITY	1.000	0.857	1.000	1.000	0.917	0.938
OPERATIONAL LAUNCH SITES	KOUROU	KOUROU	KOUROU	KOUROU	KOUROU	KOUROU

FIGURE 2.5 ARIANE 4 VARIANTS AND PAYLOAD CAPACITIES.

orbit when the flow of oxygen to the gas generator was restricted, leading to a significant loss of thrust and eventual burn termination by an on-board computer (References 11-14).

One of the side-effects of the two 1994 failures was a streamlining of launch preparation tasks which reduced the launch cycle time from four weeks to only three weeks. The backlog of Ariane missions and high traffic demand are likely to combine for a record number of launches during the 1995-1997 period, barring further mishaps. Ariane 4 is scheduled to be phased out by 1998-1999 after more than 100 missions.

In early 1996 the long-awaited Ariane 5 launch vehicle will begin flight operations in an effort to accommodate larger GEO spacecraft as well as to permit the launch of large man-related spacecraft into LEO. Ariane 5 will be somewhat shorter but much broader than its predecessor (Figure 2.6). The basic launch vehicle consists of a large, liquid-propellant central stage surrounded by two large, solid propellant boosters. The central stage (H155)

will be powered by a single Vulcain engine developed by SEP and burning liquid oxygen/liquid hydrogen. The booster stages (P230) are analogous to the boosters used by the US STS and are designed to be recovered from the Atlantic Ocean and refurbished. This configuration was sized to place the now-cancelled 22-metric-ton Hermes spaceplane into a low altitude transfer orbit: 100 km by 460 km, 28.5° inclination (References 2, 15-22).

For GTO or other LEO missions, a small upper stage (L9, formerly L7) burning nitrogen tetroxide and monomethylhydrazine through a single Aestus engine will be employed. Payload capacity for this type of mission varies from 5.1 to 6.8 metric tons depending upon the number of payloads carried. Multiple payload housing systems called SPELTRA (Structure Porteuse Externe de Lancements Triples Ariane) can accommodate two or three major satellites (References 23-24). The L9 stage was also designed to place the unmanned Columbus module into LEO.

The principal contractors for Ariane 5 are Aerospatiale (central stage), SEP (Vulcain engine), Europropulsion and Aerospatiale (booster stage and engine), and DASA/ERNO (upper stage). The first hot test of a reinforced P230 solid booster took place on 16 February 1993, followed by a flight-design booster test on 25 June 1993. Difficulties with the Vulcain engine were resolved in 1993-1994, and the first phase of the development program was completed in late 1994 (References 25-27). Under an ESA contract the Russian Scientific Research Institute for Parachute Making is designing an improved booster stage recovery system which could replace the original ESA system (References 28-30).

After years of testing the Vulcain engine (since 1990), an Ariane 5 first stage non-flight "battleship" (reinforced) configuration was fired for the first time on a pad at the Kourou space launch facility on 17 November 1994. Although several months late, this program milestone demonstrated many key features of the critical Kourou infrastructure necessary for Ariane 5 missions. Meanwhile, the development phase of the L9 upper stage was completed, and Switzerland's Oerlikon-Contraves Space tested the large Ariane launch shroud, both in late 1994 (References 31-34).

Current estimates for Ariane 5 flight rates range from 5-10 per year with some payloads

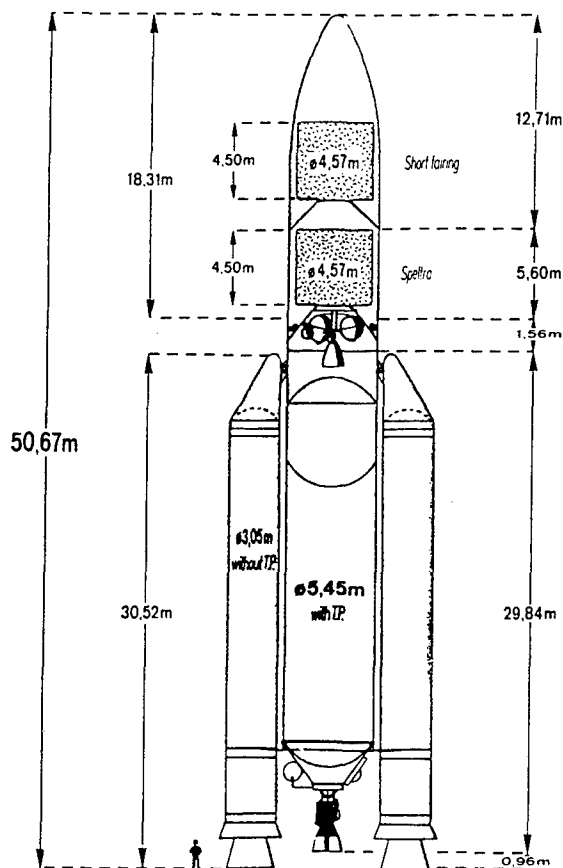


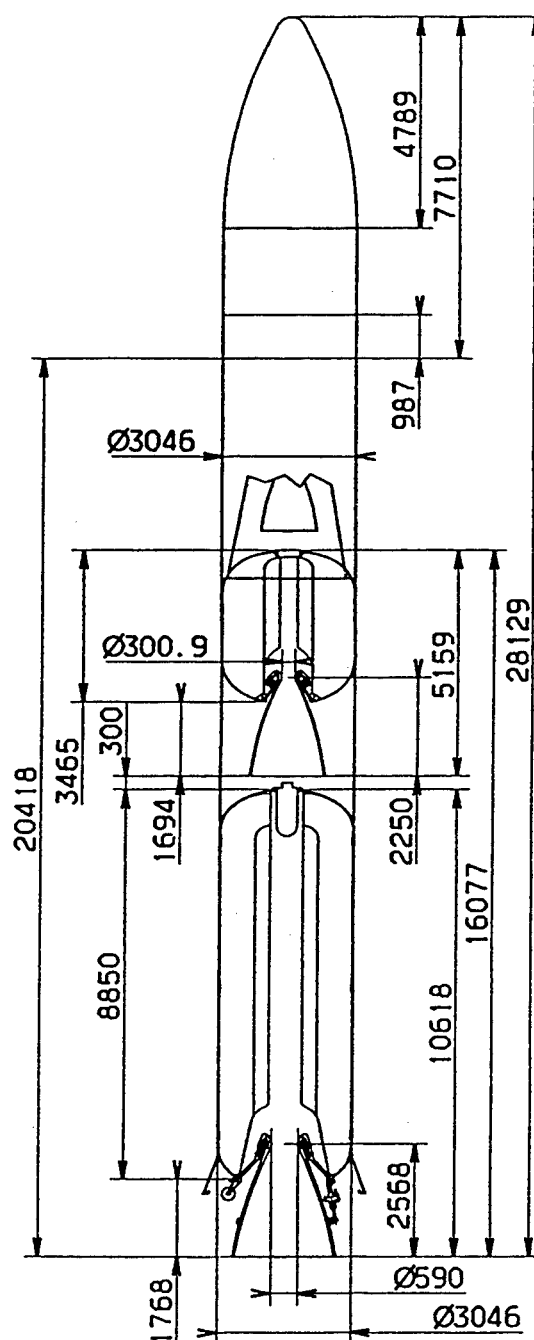
FIGURE 2.6 ARIANE 5 DESIGN.



Specific Ariane 5 enhancements, including an improved Vulcain main engine and a change in the ratio and mass of the propellants, represent a near-term improvement which could increase the booster payload capacity to LEO by two metric tons. By combining the new main engine with two additional strap-on boosters, the LEO capacity could be increased by more than seven metric tons. This concept would employ two P130 boosters which are shortened versions of the standard P230 boosters and which would be ignited at altitude to avoid costly pad modifications. Another option includes replacing the small L9 upper stage with a more capable unit, e.g., the L15. To effect a much greater lift capability, preliminary designs envision a significant increase in the size of the central stage which would be equipped with five improved Vulcain engines and would be surrounded by four P230 boosters (References 42-45).

FESTIP is also continuing ESA's Reusable Rocket Launcher (RRL) studies aimed at applying Ariane 5 technologies to partially or

ESA's once high-priority Hermes spaceplane program was officially canceled in



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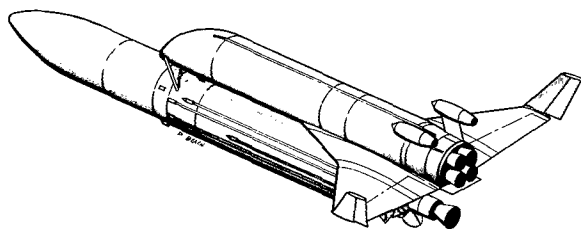


FIGURE 2.8 ARIANE REUSABLE ROCKET LAUNCHER CONCEPT.

1993 after it had been severely curtailed to an ESA-Russian technology development program the previous year (References 52-57). Two other proposed man-related space transportation programs, the Crew Transport Vehicle and the Automated Transfer Vehicle, are described in Section 3.1 of this report.

All Ariane launches are conducted at ESA facilities located on the French Centre Spatial Guyanais grounds in Kourou, French Guiana. Kourou was the site of eight launches of the French Diamant B/BP boosters during 1970-1975 before the maiden flight of Ariane 1 in 1979. Currently, only one launch pad, ELA-2, is operational for all Ariane 4 missions. Another pad, ELA-3, is nearing completion for the larger Ariane 5. Both pads are designed for rapid refurbishment in case of a major launch vehicle accident. Launches are conducted essentially eastward for GTO missions and to the northeast or northwest for LEO posigrade and retrograde orbits, respectively.

In 1993 a major multi-year renovation project was undertaken in Kourou to support not only the forthcoming Ariane 5 but also the continuing Ariane 4 missions. By the end of 1994 nearly all Ariane 5 support facilities were finished or nearing completion, and the first on-pad tests of the Ariane 5 main stage had been achieved. In addition, improvements to radar, telemetry, telecommunications, and operational facilities were underway. Also in 1994 Aerospatiale and Russia's Khrunichev State Space Research and Production Center discussed the feasibility of building launch facilities for the Proton-M at Kourou (References 57-60).

## 2.2 GERMANY

Following the lead of France with its Hermes spaceplane, Germany and the major German aerospace industries are investing considerable resources in the preliminary design and technology development of an advanced transportation system with hopes that ESA will adopt the program for full-scale development and operation. Named in honor of the German engineer whose pioneering work in the first half of the 20th century fostered the present-day concept, DASA's Sanger project is based on a two-stage, fully reusable aerospace plane which would take off and land horizontally like conventional aircraft (Figure 2.9).

The first stage is a large (>80 m long, >40 m wing-span), unmanned hypersonic aircraft powered by hybrid, air-breathing turbo-ramjets to carry a smaller Hypersonic Orbital Reusable Upper Stage (HORUS) to an altitude of approx-

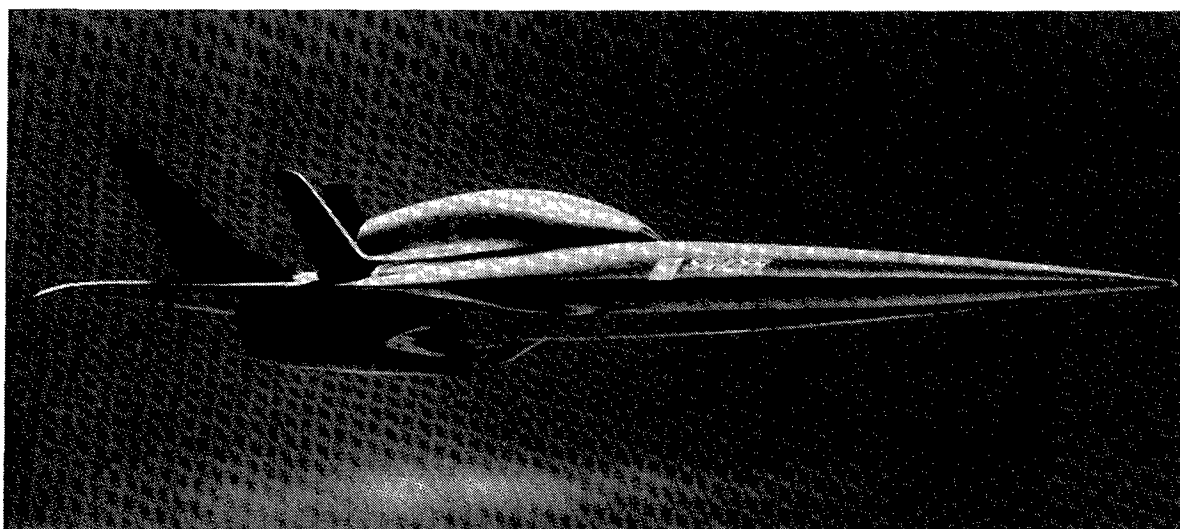


FIGURE 2.9 SANGER REUSABLE SPACE TRANSPORTATION SYSTEM.

imately 40 km. HORUS would then separate at a speed of more than Mach 6 and ignite conventional liquid oxygen/liquid hydrogen engines to reach LEO. With a 4-man crew, HORUS would be capable of delivering up to three metric tons to a baseline 450-km, 28.5°-inclination orbit. An unmanned version of HORUS, HORUS-C, could deliver up to seven metric tons of cargo and return a like amount to Earth.

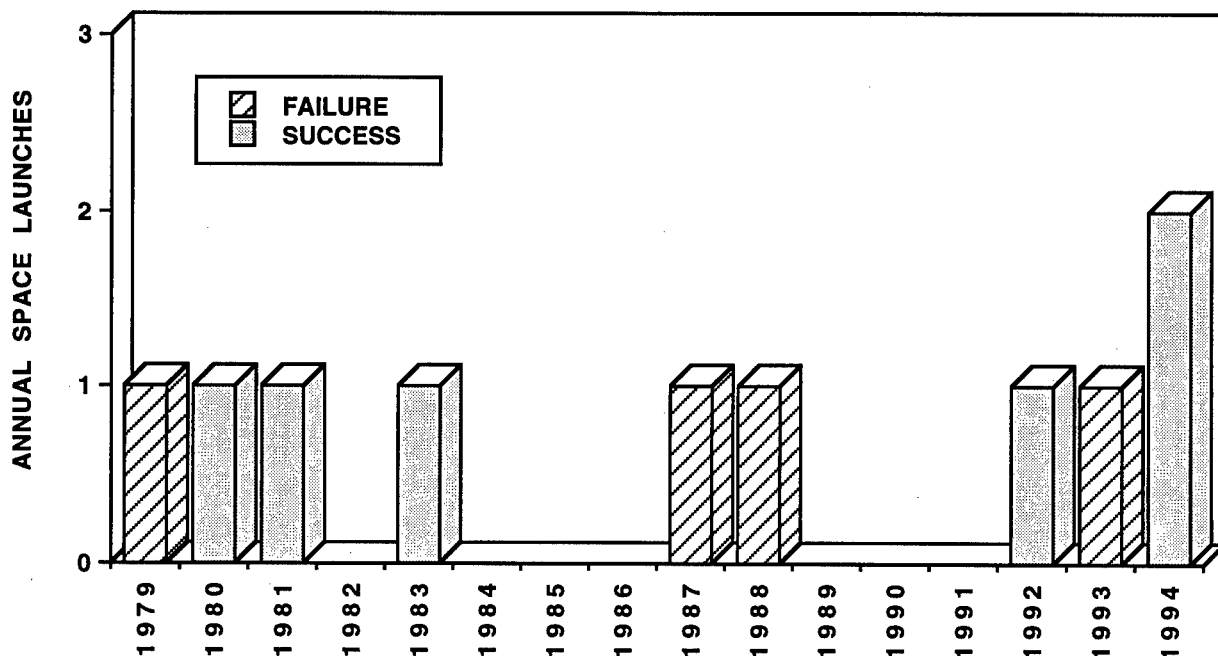
Currently sponsored by the Federal Ministry of Research and Technology under Phase 1 of the German Hypersonics Technology Program (HTP) begun in 1988 and extended to 1995, Sanger requires international cooperation to move into Phase 2 which would develop a hypersonic flight demonstrator by about the year 2000. However, in 1994 Germany joined ESA's FESTIP where it hopes to continue its hypersonics technology research.

Meanwhile, Germany is continuing state-of-the-art technology development of turbo-ramjet engines and is designing semi-reusable, single-stage-to-orbit (SSTO) space transportation systems. The latter is represented by the ADLER concept with a 60 metric ton payload capacity to a 450-km, low-inclination Earth orbit. ADLER's Reusable Acceleration and Avionics Module (RAAM) may be powered by either nine Russian RD-0120 or nine US SSME cryogenic engines (References 61-67).

In the near-term Germany is working with the Russian Federation to develop two commercial, low capacity launch vehicles. In 1994 DARA funded feasibility studies for the proposed air-launched (from a Tu-160 aircraft) Burlak booster with a maximum payload capacity of 1,100 kg (Reference 68). Likewise, DASA was evaluating the commercial potential of the Russian Rokot launch vehicle (up to 2,000 kg capacity), which conducted its first orbital mission in December 1994 (see Section 2.9 for additional specifications of the Burlak and Rokot launch vehicles).

### 2.3 INDIA

Following on the heels of the first successful launch of its Augmented Satellite Launch Vehicle (ASLV) in 1992, India tested the more capable Polar Satellite Launch Vehicle (PSLV) during 1993-1994, achieving success on the second attempt. Coupled with another ASLV mission in 1994, India's three launch attempts in the two-year period represented its most active campaign since its indigenous space program began in 1979 (Figure 2.10). Meanwhile, the development of India's substantially larger Geosynchronous Satellite Launch Vehicle (GSLV) continues toward a projected maiden flight later in this decade.



\* 1981 AND 1992 MISSIONS DID NOT REACH INTENDED ORBIT

FIGURE 2.10 INDIAN LAUNCH VEHICLE FLIGHT RECORD.

The original Indian SLV-3 launch vehicle was a four-stage, solid-propellant booster with a LEO payload capacity of less than 50 kg into an orbit with a mean altitude of 600 km at an inclination of 47°. Following an initial failure, the SLV-3 successfully orbited three Rohini Satellites in 1980, 1981, and 1983, respectively (Reference 69). The ASLV was created by adding two additional boosters modified from the SLV-3's first stage and by making other general improvements to the basic SLV-3 4-stage stack (Figure 2.11). The ASLV is actually a five-stage vehicle since the core first stage does not ignite until just before the booster rockets burn out. The payload capacity of the ASLV is approximately 150 kg to an orbit of 400 km with a 47° inclination (Reference 70).

The first launch of the ASLV on 24 March 1987 failed when the bottom stage of the core vehicle did not ignite after booster burn-out. The second attempt ended with the Rohini payload falling into the Bay of Bengal on 13 July 1988 when the vehicle became unstable and broke up soon after release of the booster rockets. Finally, on 20 May 1992 the SROSS 3 (Stretched Rohini Satellite Series) was inserted into LEO by the third ASLV. However, instead of obtaining a circular orbit near 400 km, the ASLV only achieved a short-lived orbit of 256 km by 435 km, not unlike the degraded performance of the SLV-3 launch of 31 May 1981 (Reference 71).

The fourth ASLV mission in May, 1994 successfully reached its programmed orbit of 434 km by 921 km with the SROSS C2 payload. The vehicle is likely to be phased out shortly in favor of the PSLV and due to a desire to deploy larger, more complex spacecraft than can be lifted by the ASLV.

The PSLV was developed to permit India to launch its own IRS-class satellites into sun-synchronous orbits, a service until recently procured commercially via the USSR/CIS. The design orbital capacity for the PSLV is one metric ton into a 900 km, 99° inclination orbit. This significant increase in lift is achieved using a 5-stage design similar to the ASLV: a 4-stage core vehicle surrounded by six strap-on boosters of the type developed for the ASLV. At lift-off only two of the strap-ons and the bottom stage of the core vehicle are ignited. The other four boosters are fired at an altitude of 3 km.

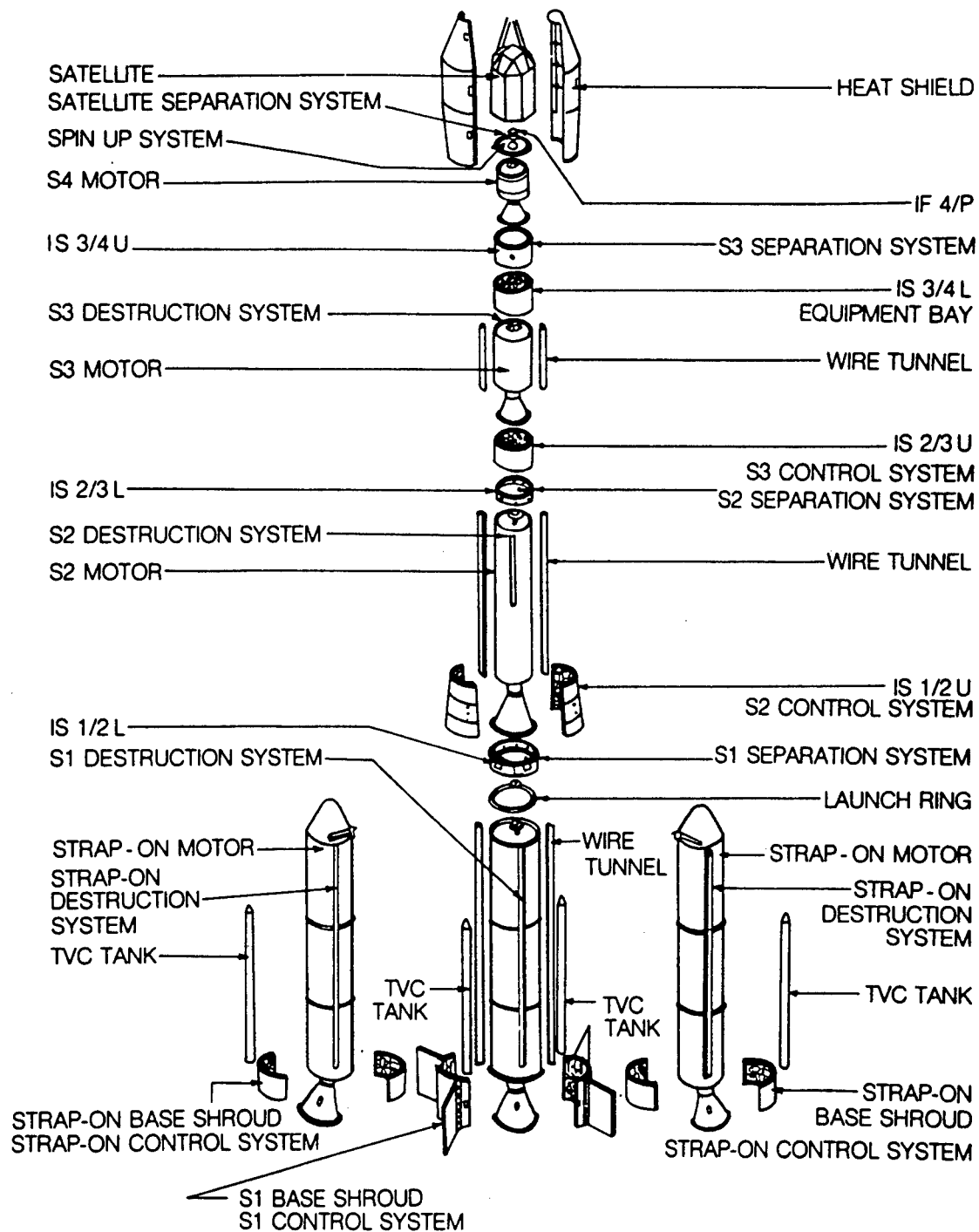
The core vehicle possesses an unusual design consisting of two solid-propellant stages

(1 and 3) and two liquid, hypergolic stages (2 and 4). The first stage also carries two cylindrical tanks which are part of the Secondary Injection Thrust Vector Control System (STIVC). The large liquid engine of the second stage is designated Vikas and is essentially an Indian-manufactured Viking engine used by ESA's Ariane. During 1992 all four stages were certified for flight in 1993, and full vehicle integration tests were performed (References 70 and 72).

After some delays the maiden flight of the PSLV with the IRS-1E Earth observation spacecraft occurred on 20 September 1993. Although all strap-ons and main engines performed as expected, an attitude control problem arose after separation of the second and third stages. Consequently, the vehicle and its payload failed to reach Earth orbit. A little more than a year later, on 15 October 1994, the IRS-P2 spacecraft was inserted into the prescribed sun-synchronous orbit by PSLV no. 2. Almost immediately afterwards, Indian officials announced plans for the manufacture of three additional PSLVs and initial construction for three more. Commercial space transportation services could be available by 1996 (References 73-80).

In the 1980's India began designing the GSLV with an objective of placing 2.5 metric ton payloads into GTO. Drawing heavily on the PSLV, early concepts for the GSLV would borrow the six strap-on boosters and first two stages of the PSLV's core vehicle. A later design suggested replacing the solid strap-on boosters with four liquid units similar to the second stage of the core vehicle. The third stage was to incorporate an indigenous liquid oxygen/liquid hydrogen engine with a thrust of approximately 12 metric tons. Component development for this engine was already underway in the late 1980's, and subscale development was still on-going in 1992 (References 70, 81, and 82).

However, in an attempt to maintain the GSLV development schedule which now calls for a first flight as early as 1997, India in 1992 contracted with Russia to buy a liquid oxygen/liquid hydrogen engine (KVD-1/KVD-7.5) developed in the 1970's for the heavy-lift N-1 launch vehicle. The plan, which had been in negotiations since 1988 came under fire from the US which considered the transfer of such technology a violation of the Missile Technology



SALIENT FEATURES	
PAY LOAD	: 150 KG IN 400 KM CIRCULAR ORBIT
LIFT-OFF WEIGHT:	39 TONNES
HEIGHT	: 23.5 METRES
MAX. DIA	: 1.00 METRE

FIGURE 2.11 ASLV LAUNCH VEHICLE COMPONENTS.

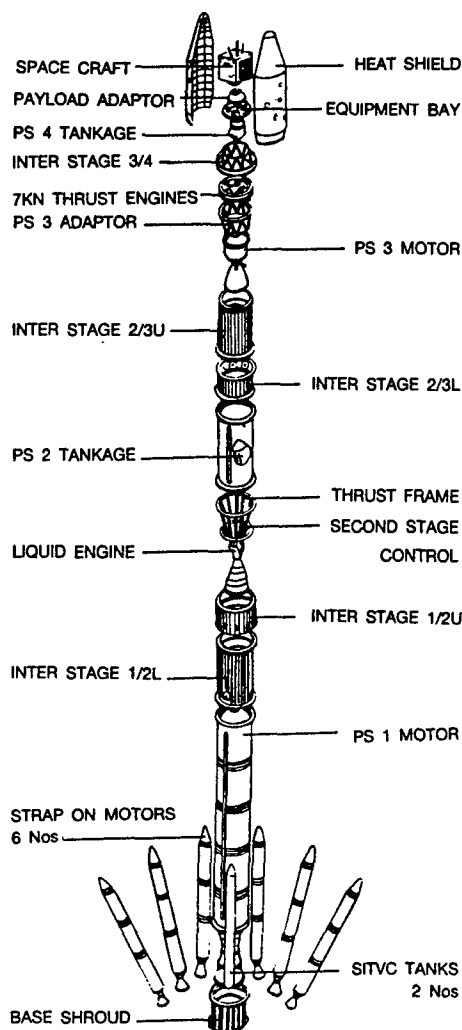


FIGURE 2.12 PSLV LAUNCH VEHICLE COMPONENTS.

Control Regime. Eventually, a compromise was reached which allowed the Russian Federation to supply a limited number of engines to India (seven) without the transfer of critical technologies. The first engine is scheduled to be delivered in 1996 for the inaugural GSLV mission in late 1997 or early 1998. Test firings of lower stage GSLV motors were underway in 1994 (References 83-96).

In October, 1992, India conducted sub-orbital tests of model air-breathing rocket engines mounted on small conventional launch vehicles. The development program was initiated in the late 1980's and is said to be applicable to the creation of future hypersonic boosters. Although few details have been released, both flights were described as successful (References 97 and 98).

All Indian space launches are conducted from the Sriharikota High Altitude Range (SHAR) on Sriharikota Island off the east coast of India in the Bay of Bengal. The original SLV-3 launch complex was converted to support the ASLV. Two new complexes with one pad each to the south were selected to support the PSLV and GSLV. The Vikran Sarabhai Space Center at the southern tip of India is the site of most launch vehicle stage development.

## 2.4 ISRAEL

Israel's Shavit (Comet) launch vehicle has flown only twice - 19 September 1988 and 3 April 1990 - to place the Ofeq 1 and Ofeq 2 engineering technology satellites into LEO. The third flight of Shavit was postponed in early 1994 until 1995, in part, due to budgetary constraints. Shavit is a small, 3-stage, solid-propellant booster based on the 2-stage Jericho 2 ballistic missile and developed under the general management of Israeli Aircraft Industries and in particular its MBT Systems and Space Technology subsidiary. Israel Military Industries produces the first and second stage motors, while Rafael is responsible for the third stage motor (Figure 2.13). The demonstrated payload capacity is 160 kg into an elliptical orbit of 207 km by 1,587 km with a highly retrograde inclination of 143.2°. Shavit was proposed to launch an American commercial recoverable spacecraft (COMET) which would have required a payload of 800 kg or more inserted into a low altitude orbit (References 99-101).

The upper stage of the Shavit is designated AUS-51 (Advanced Upper Stage) and since September, 1992, has been offered commercially under a cooperative venture by the Israeli firm Rafael, which developed and manufactures the AUS-51, and the American Atlantic Research Corporation. A much more capable upper stage is under development by Israeli Aircraft Industries for much larger launch vehicles with a GEO objective. Called the Cryogenic Transfer Module (CTM), the stage burns liquid oxygen and liquid hydrogen to produce a thrust of approximately one metric ton. CTM is designed to lift a 2.1 metric ton satellite from a 200 km, 28° parking orbit to GEO and was scheduled to be ready for flight by the end of 1992 but was still awaiting a mission as 1994 came to a close (References 102 and 103).

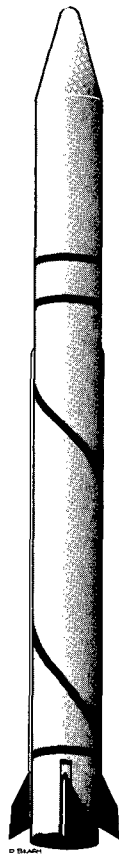


FIGURE 2.13 SHAVIT LAUNCH VEHICLE.

In 1993-1994 Israel proposed the development of an improved Shavit launcher called Next, which would be available to the international commercial market. The standard 3-stage Next launch vehicle would differ little from Shavit and could deliver up to 400 kg payloads to polar orbits from launch sites outside Israel. A 4-stage variant of Next is envisioned with extended first and second stages and a new liquid propellant fourth stage equipped with a GPS receiver for greater orbital insertion accuracy (References 104-106).

Shavit boosters are launched from an undisclosed site near the Palmachim Air Force Base on the coast of Israel south of Tel Aviv. The facility is also sometimes referred to as Yavne. To prevent overflight of foreign territory, Shavits have been launched on a northwest trajectory over the Mediterranean Sea, passing over the Straits of Gibraltar at the west end of the Mediterranean. This procedure significantly reduces the payload capacity of the launch vehicle and severely limits potential operational orbits.

## 2.5 ITALY

Although nine space launches were conducted by Italy during 1967-1988, all employed variants of the US-built Scout booster to orbit small scientific satellites prepared by Italy, the UK, or the US. The vehicles are completed in the US prior to shipping to the Italian launch facility for final testing and launch. However, this arrangement has provided Italy with valuable launch operations experience.

The Italian firm BPD Difesa E Spazio is the prime contractor for the Ariane 4 solid-propellant strap-on boosters and is a principal developer of the larger Ariane 5 solid-propellant booster. Meanwhile, Alenia Spazio in cooperation with BPD has developed the solid-propellant Italian Research Interim Stage (IRIS) for use by a variety of international launch vehicles. Its first mission was the successful transfer of Italy's LAGEOS 2 satellite from a US Space Shuttle to a high altitude operational orbit in October, 1992.

Italy's desire to acquire a more capable and more independent space launch capability ran into trouble in 1992 when competing designs from the Italian Space Agency and the University of Rome became embroiled in a legal dispute. Since 1988 the Italian Space Agency has been examining the possibility of developing a Scout 2 launch vehicle based on the first three stages of the US Scout G-1. Italy would add two large, solid-propellant, strap-on boosters and possibly a new fourth stage. The strap-on boosters would be derived from BPD's Ariane 4 boosters. The University of Rome, which operated the Italian Scout launch facility, supported this program which would increase Italy's LEO payload capacity to 500 kg.

However, in recent years the Italian Space Agency has preferred a more radical design employing a greater degree of national space technology and less dependence on the US. In March, 1992, the experimental Zefiro rocket, which would serve as the new launch vehicle's first stage with two strap-on boosters was flown for the first time - albeit with mixed success. Unwilling to support two, essentially redundant Scout upgrade programs, the Italian Space Agency began withholding development funds from the University of Rome, prompting the latter to file suit. By early 1993 funding for the University of Rome's Scout program had resumed, but the dispute had not been resolved.

Finally, in the second half of 1993, the Scout 2 program was terminated after a decision was made to concentrate on an Italian design. Leveraging off the Zefiro development program, the new Vega launch vehicle will have a 700-800 kg LEO capacity. The 3-stage, solid-fuel booster will rely on Zefiro motors for the first two stages with IRIS serving as a third stage. However, a reduction in government funding has forced BPD Difesa E Spazio to underwrite the initial development work with an uncertain maiden launch date (References 107-115).

Although the 1992 test launch of the sub-orbital Zefiro was conducted from the island of Sardinia, all Italian space launches to date have originated from the San Marco launch platform off the coast of Kenya in Formosa Bay. With a latitude less than three degrees from the equator, San Marco offers nearly optimum payload capacity for satellite missions with low inclination. However, much larger launch vehicles would be required to support the more popular GTO/GEO missions. A second sea-based platform near San Marco supports the necessary launch control facilities.

## 2.6 JAPAN

Japan's long-awaited H-II launch vehicle debuted during 1994 and achieved two complete successes on its first two missions.

The National Space Development Agency of Japan's (NASDA) new medium-lift launch vehicle will support a variety of major programs during the next decade and may become Japan's first entry into the international commercial launch services market. Meanwhile, Japan's Institute of Space and Astronautical Science neared the end of its light-lift M-3SII program with yet another successful commercial launch in 1993. Nearing completion of development and maiden flights are two new low-capacity boosters: the M-5 and the J-I. Japan has not lost a spacecraft due to a domestic launch vehicle or upper stage failure since 1980 (Figure 2.14).

ISAS's current M-3SII launch vehicle has been in operation since 1985 and had performed flawlessly on all seven missions by the end of 1994. The booster is a descendant of the M-4S first flown in 1970. The only flight during 1993-1994 occurred on 20 February 1993 when the 420-kg Astro-D (aka Asuka) X-ray observatory was inserted into an orbit of 538 km by 647 km with an inclination of 31.1°. The maximum lift capacity for the M-3SII is approximately 800 kg into a 250 km circular, 31° orbit (References 116 and 117).

The M-3SII is a 3-stage, all solid-propellant launch vehicle with two strap-on boosters and a family of optional fourth stages which are tailor-made for specific mission profiles (Figure 2.15).

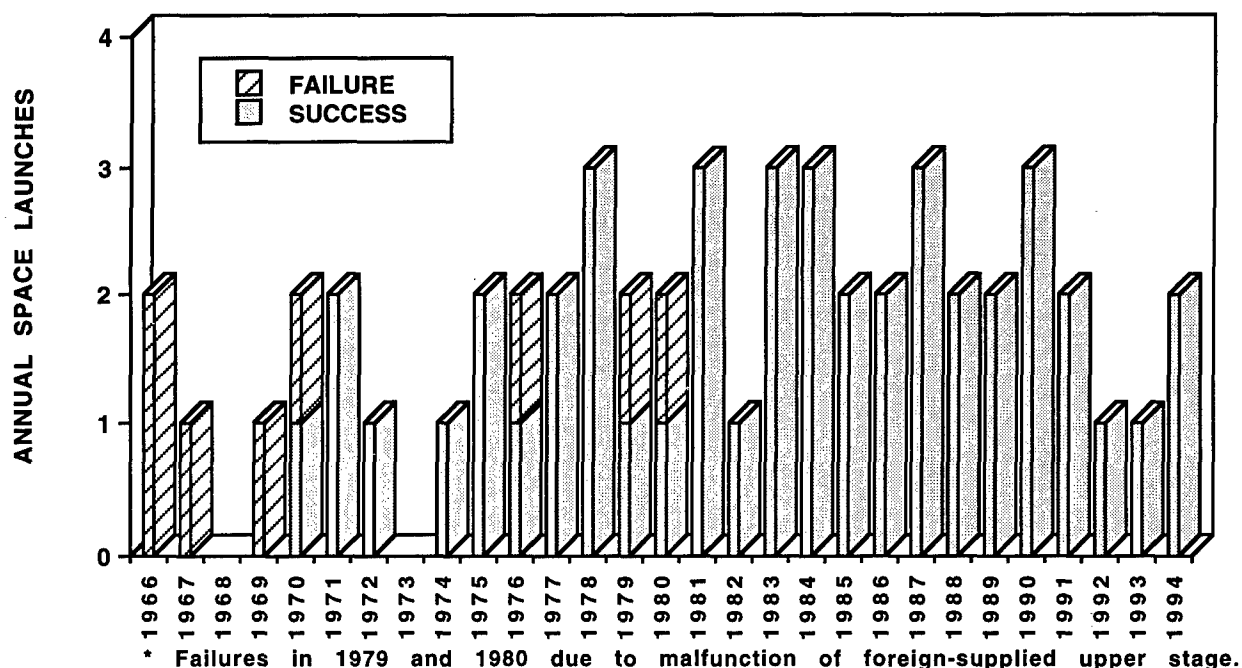


FIGURE 2.14 JAPANESE LAUNCH VEHICLE FLIGHT RECORD.



All four stages as well as the strap-on boosters are manufactured by the Nissan Motor Company. In addition to LEO missions, the M-3SII has placed spacecraft on Earth escape trajectories (Sakigake and Suisei in 1985) and into extremely high altitude orbits with apogees beyond lunar distances (Muses-A in 1990). The final flight of the M-3SII was scheduled to take place in early 1995 in support of the German-Japanese-Russian microgravity recoverable satellite program, EXPRESS (Section 4.4.3).

The inaugural flight of the new M-5, a 3-stage, solid-propellant system capable of lifting 1.8 metric tons into a LEO of 250 km (Figure 2.15), has been delayed until 1997, primarily due to technical difficulties. On 21 June 1994 the M-5 first stage motor was

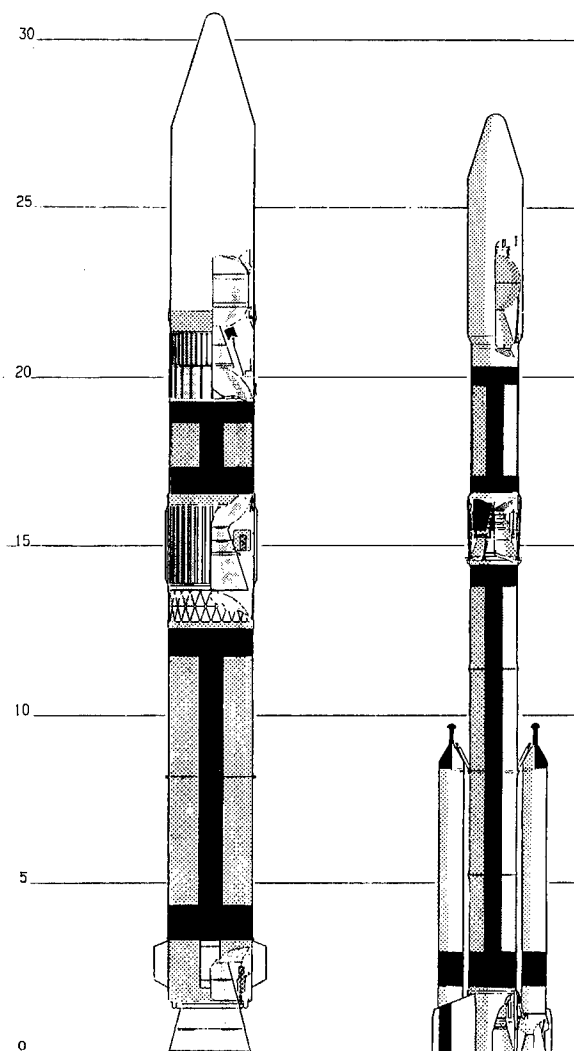


FIGURE 2.15 M-5 AND M-3SII LAUNCH VEHICLES.

successfully tested at ISAS' Noshiro rocket test site, and another test with a flight-design model was slated for 1995. Plans to employ extendable motor nozzles on both the second and third stages were scaled back to only the third stage. Produced jointly by Nissan (motors and fairing) and Mitsubishi Heavy Industries, the M-5 will permit ISAS to undertake more ambitious scientific missions, particularly beyond Earth orbit, e.g., a lunar mission in 1997 and a mission to Mars in 1998 (References 118-124).

Since 1975 NASDA has been conducting a parallel program of launching Japanese satellites for space technology and applications purposes using liquid-propellant vehicles. The original N-series (N-I and N-II) launch vehicles were developed under license from the US and were closely related to the Delta launchers. Flown during 1975-1987, the N-series was replaced by the H-I launch vehicle (first flight in 1986), a hybrid US-Japanese design. The first stage of the H-I was essentially the same as that of the N-II with a liquid oxygen/kerosene main engine and 6-9 small solid-propellant strap-on boosters. The second stage was of Japanese origin, built by Mitsubishi Heavy Industries, and burned liquid oxygen and liquid hydrogen. A small solid-propellant third stage designed by Nissan was employed on GEO missions to place the payload (up to 1,100 kg) into GTO (References 116 and 125). The H-I program concluded in 1992 with nine successes and no failures.

To provide greater payload capacity and to permit unencumbered commercial space transportation offerings (the Delta licensing agreement restricted the use of the H-I for commercial flights), Japan developed the H-II launch vehicle based on all-Japanese propulsion systems. The H-II can lift payloads four times heavier than the H-I into LEO (up to 10 metric tons) and GTO (up to 4 metric tons) and will open the door to NASDA spacecraft designed to explore the Moon and planets. The first mission on 3 February 1994 deployed one payload into LEO and then carried an experimental package VEP (Vehicle Evaluation Payload) to GTO. The next H-II mission on 28 August deployed the 3.8 metric ton ETS-VI spacecraft.

Dwarfing its predecessor (Figure 2.16), the H-II consists of a 2-stage core vehicle, burning liquid oxygen and liquid hydrogen in both stages, with two large solid-propellant strap-on boosters. Nissan produces the 4-segmented

strap-on boosters which are considerably larger than the main stages of ISAS' M-3 and M-5 series vehicles. The LE-7 first-stage main engine (Table 2.2) overcame numerous developmental difficulties, while the LE-5A engine used by the second stage merely represents an upgraded version of the proven LE-5 flown on the second stage of the H-I (References 125-133).

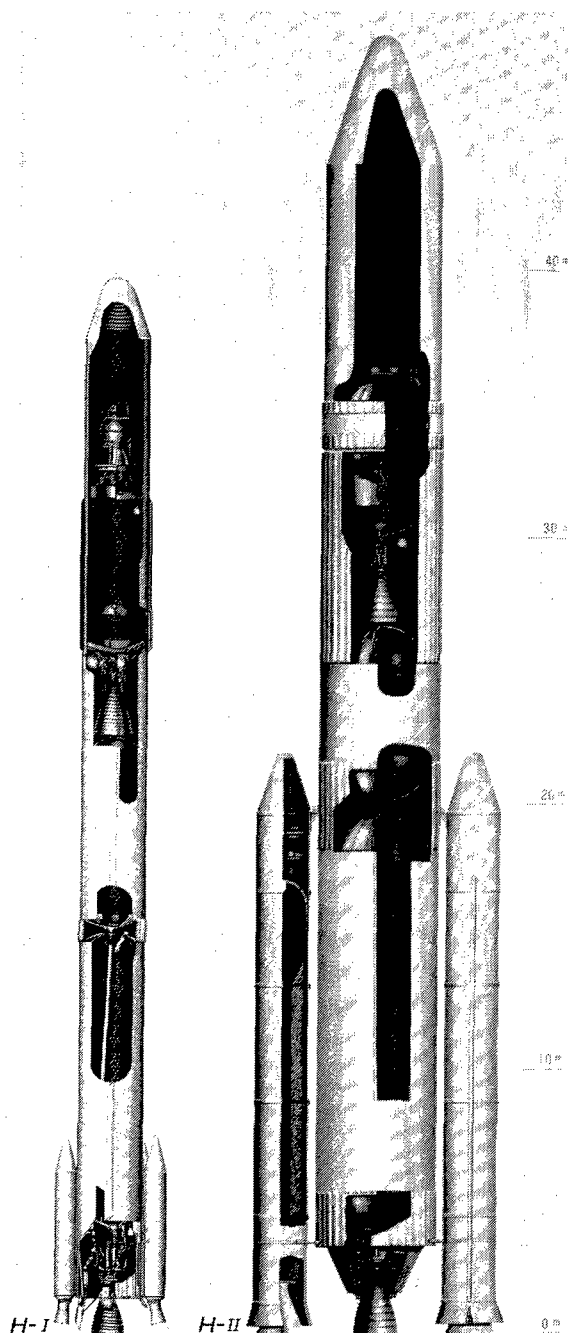


FIGURE 2.16 H-I AND H-II LAUNCH VEHICLES.

A third new launch vehicle concept emerged during 1991-1992. Called J-I, the new booster would serve the small satellite community with a one-metric-ton payload capacity to LEO in its basic configuration. After some evolution the J-I design solidified around a 3-stage, solid-propellant vehicle using a modified H-II strap-on booster for the first stage and the second and third stages of the current M-3SII, with a LEO payload capacity of up to 900 kg. Growth options include adding two or more small strap-on boosters or augmenting the first stage with two additional H-II class strap-ons. The project, approved in 1993, is being sponsored by NASDA with cooperation from ISAS. The first orbital mission is scheduled for 1998, but a 2-stage sub-orbital mission, HYFLEX (Hypersonics Flight Experiment) may be conducted as early as 1996. HYFLEX will test design and modeling principles critical to the development of future spaceplanes (References 124 and 135-139).

In addition to lofting larger GEO satellites, the H-II has been designed specifically to accommodate the proposed HOPE (H-II Orbiting Plane) spacecraft (see also Section 3.4). In its current configuration HOPE will have a launch mass of approximately 10 metric tons, a length of 11.5 m, and a wing-span of 8.6 m (Figure 2.18). Originally viewed as a major logistical vehicle for the Japanese Experiment Module of the Freedom Space Station, HOPE will initially be an unmanned spacecraft with a one-metric-ton payload capacity which could service the new International Space Station after the turn of the century. The maiden flight of a NASDA HOPE demonstration vehicle (HOPE-X) is tentatively scheduled for 1999.

A number of major technology experiments are already underway. The Orbiting Re-entry Experiment (OREX) was carried on the first H-II mission in 1994 to test navigational and thermal control systems for HOPE. In 1996 the J-I HYFLEX mission will further examine aerodynamic characteristics of hypersonic vehicles while the ALFLEX (Automatic Landing Flight Experiment) will test unmanned landing systems. Russian aerospace specialists will also assist Japan in conducting high-speed aerodynamic experiments on HOPE models at the Zhukovskiy Central Aerohydrodynamics Research Institute in the Moscow region (References 125 and 140-148).

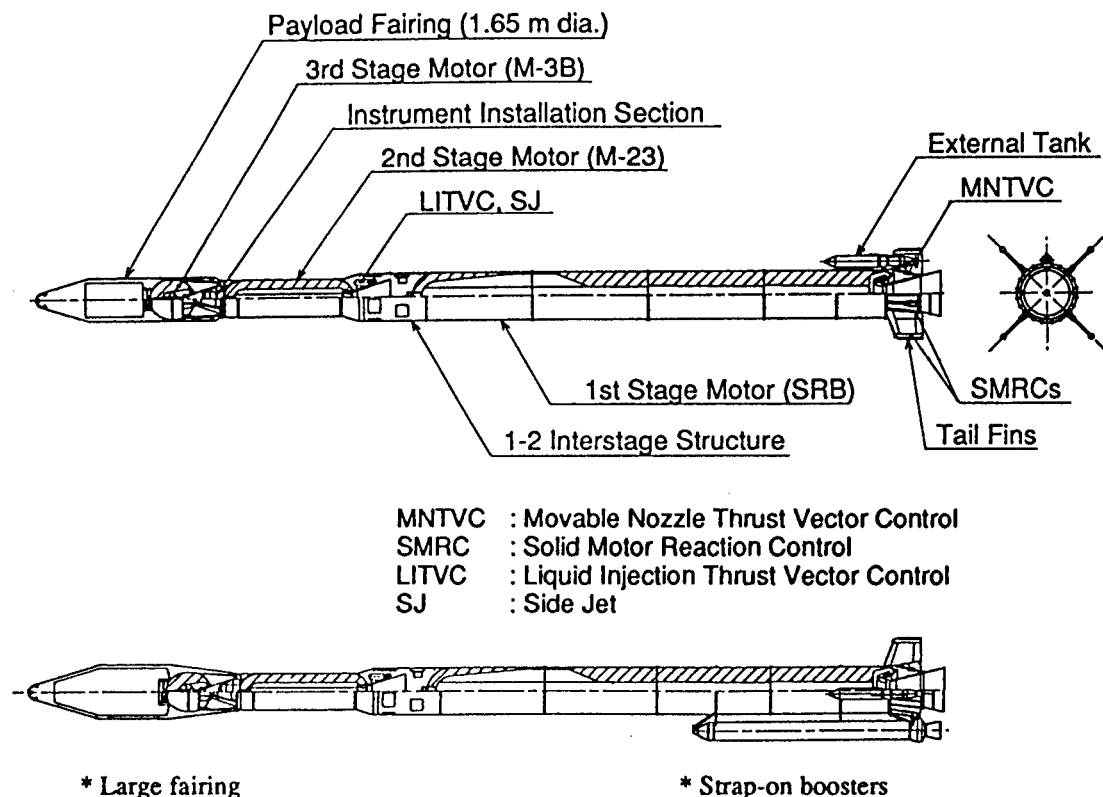


FIGURE 2.17 J-I LAUNCH VEHICLE DESIGN.

A 20-metric-ton version of HOPE, possibly manned with a 3-3.5 metric ton payload capacity, has also been considered. Such a vehicle would be 16 m long with a wing-span of 12.3 m. To support the larger HOPE, the H-II launch vehicle would require additional strap-on boosters (up to six solid boosters or a combination of solids and liquids). However, preliminary engineering analyses suggest that the new H-2D would still not be able to insert the larger HOPE directly into orbit, requiring HOPE to burn up to four metric tons of propellants to enter LEO. Meanwhile, studies of other reusable spacecraft, including single-stage-to-orbit concepts, are underway (References 149-152).

ISAS and NASDA conduct their space launch activities at two separate sites. The oldest facility is known as the Kagoshima Space Center and is maintained by ISAS on Kyushu Island. All M-3SII missions are launched from Kagoshima which will also support future M-5 flights. NASDA operates the Tanegashima Space Center on the island of Tanegashima south of Kagoshima for all H-class vehicle launches. The H-I launch pad is currently being modified to support the new J-I vehicle. A new

facility about 1 km away was constructed for H-II operations. Due to strict fishing industry requirements, all Japanese launches from both Kagoshima and Tanegashima are limited to two 2-month periods each year: January-February and August-September. Consequently, the current maximum flight rate each year is two M-class, two J-class, and two H-class launch vehicles.

## 2.7 NORWAY

Norway's Andoya Rocket Range has conducted approximately 600 sounding rocket launches since 1962 and since 1972 has directly supported numerous ESA scientific experiments. Andoya's high latitude location (~69° N) is ideal for Arctic upper atmospheric research as well as microgravity experiments. In 1993 the Norwegian Space Center in cooperation with the Swedish Space Corporation proposed the establishment of a Polar Satellite Service to launch small (up to 250 kg) spacecraft into LEO inclinations of 70° to 110°. An early survey of potential launch vehicles identified the American-led Pacastro launch vehicle development program as highly suitable for Andoya with launches beginning as

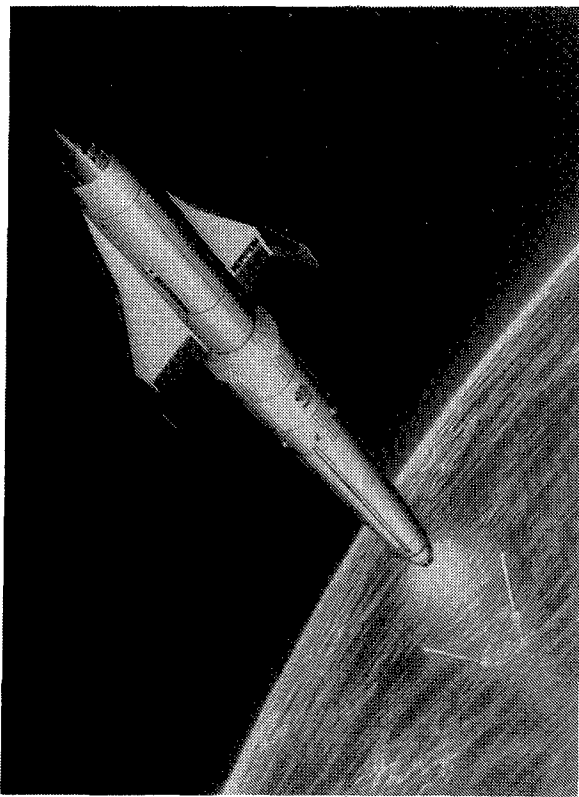


FIGURE 2.18 HOPE / ARIANE 5 SPACE TRANSPORTATION SYSTEM.

early as 1996. Subsequent decisions by Sweden to cooperate more closely with the Russian Federation have undercut the likelihood that the Polar Satellite Service will commence operations in the near term (References 153-157).

## 2.8 PEOPLE'S REPUBLIC OF CHINA

Since 1970 the PRC has conducted more than 40 space launches, although its failure rate of more than 20% is substantially higher than its primary Eurasian competitors: CIS, ESA, and Japan (Figure 2.19). Despite a relatively low domestic launch demand - typically 2-3 satellites annually - the PRC has developed and is expanding, in part for commercial reasons, a diverse arsenal of launch vehicles to support both LEO and GEO missions. Since 1988, the PRC has introduced a new launch vehicle every two years.

The newest addition to the Chang Zheng (Long March) or CZ family appeared in 1994 when the CZ-3A was tested twice successfully. Thus, by the end of 1994, the PRC possessed six operational launch vehicles (Figure 2.20) with three more under development. Principal responsibility for the design and production of CZ launch vehicles lies with the China Academy

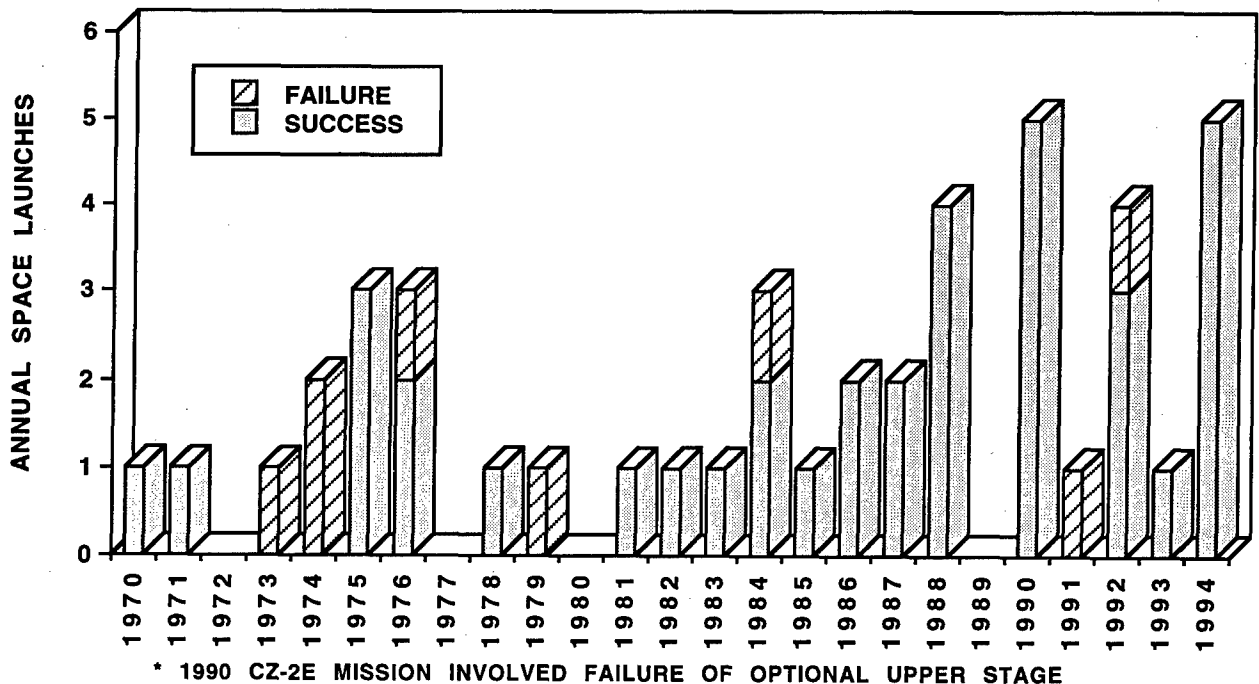


FIGURE 2.19 CHINESE LAUNCH VEHICLE FLIGHT RECORD.

of Launch Vehicle Technology and the Shanghai Academy of Spaceflight Technology, both of which belong to the newly organized China Aerospace Corporation.

The oldest operational Chinese launch vehicle is the CZ-2C which debuted in 1975 as the carrier of the FSW-class of recoverable low altitude satellites. Averaging one mission per year for the past decade, the CZ-2C has a high reported reliability and a payload capacity of 2.8 metric tons to LEO. The CZ-2C is derived from the CSS-4 ballistic missile and consists of two stages burning UDMH and nitrogen tetroxide. The single CZ-2C mission during 1993-1994 was launched on 8 October 1993 with a FSW-1 Earth observation spacecraft. Later in the decade, the CZ-2C may be mated with a small, solid-propellant perigee kick-stage to provide the vehicle with a modest GTO capability (References 158-166).

In 1990 the CZ-2E variant was introduced to give the CZ-2 series of launch vehicles a GTO capability which was specially designed to accommodate Western GEO satellites. The booster consists of a 2-stage core vehicle with four strap-on stages, all employing UDMH and nitrogen tetroxide. The strap-on stages each use a single YF-20B engine which is an improved version of the main engine design used on the first stage of the CZ-2C. Four YF-20B engines are combined to make the YF-21B which powers the first stage of the core vehicle, which is more than three meters longer than the CZ-2C first stage. The CZ-2E second stage is also based on its CZ-2C counterpart with an up-rated main engine (YF-22B) and larger propellant tanks carrying more than twice the load of the CZ-2C second stages. Finally, a small perigee kick stage is available for payload transfer from a LEO parking orbit to GTO (References 159, 162, 163, 166-169). The CZ-2E has a 9.2 metric ton LEO capacity and a 3.1-3.4 metric ton capacity to GTO depending upon the perigee kick stage selected.

The first test of the CZ-2E on 16 July 1990 successfully reached the desired LEO parking orbit with the small (50 kg) Pakistani Badr piggy-back satellite, but an attempt to test the new Chinese perigee kick stage attached to a dummy payload failed. The next mission carried the Australian Optus B1 satellite into orbit on 13 August 1992 after an initial pad launch abort on 22 March of that year. The next flight on 21 December 1992 failed when a malfunction of

the payload or shroud occurred less than one minute into the ascent. Despite the violent nature of the failure, which left a large portion of the payload scattered down range, the CZ-2E second stage continued to function and reached a nominal LEO parking orbit. The vehicle flew again successfully on 27 August 1994 with Optus B3 (References 170-179).

A third CZ-2 variant, the CZ-2D, appeared with little forewarning on 9 August 1992 in conjunction with the maiden flight of the FSW-2 spacecraft. The CZ-2D is essentially a two-stage version of the CZ-4 (below) with a LEO payload capacity in excess of three metric tons. The CZ-2D flew a second FSW-2 mission on 3 July 1994.

The CZ-3 launch vehicle was introduced in 1984 to provide the PRC with its initial GEO mission capability. The vehicle also marked the first use of a high technology upper stage and led to China's entry into the commercial space launch services market. The CZ-3 is a 3-stage launch vehicle with the first two stages essentially identical to the CZ-2C. The third stage utilizes a restartable, liquid oxygen/liquid hydrogen engine designated YF-73. The GTO capacity of the CZ-3 is 1.5 metric tons (References 159, 164, 180-184).

Although the inaugural flight of the CZ-3 on 29 January 1984 failed when the third stage did not restart to maneuver from a LEO parking orbit to GTO, the next six missions (April, 1984-April, 1990) were successful. Only one CZ-3 mission was attempted during 1991-1993, and this flight resulted in the stranding of a domestic PRC communications satellite in the wrong orbit. Lift-off occurred on 28 December 1991, and orbital insertion into the planned LEO was accomplished. However, when the third stage was reignited, a propellant pressurization malfunction caused a premature shut-down, leaving the payload with an apogee of only 2,450 km instead of nearly 36,000 km as required. The CZ-3 returned to flight on 21 July 1994, successfully inserting the APstar 1 spacecraft in GTO on a commercial mission (References 185 and 186).

With its limited payload capacity and the continued growth of GEO spacecraft, the CZ-3 was joined in 1994 by the CZ-3A. The new launch vehicle incorporates a lengthened first stage, a pair of more powerful YF-75 engines in the third stage, and an improved, light-weight flight control system. The LEO payload capacity

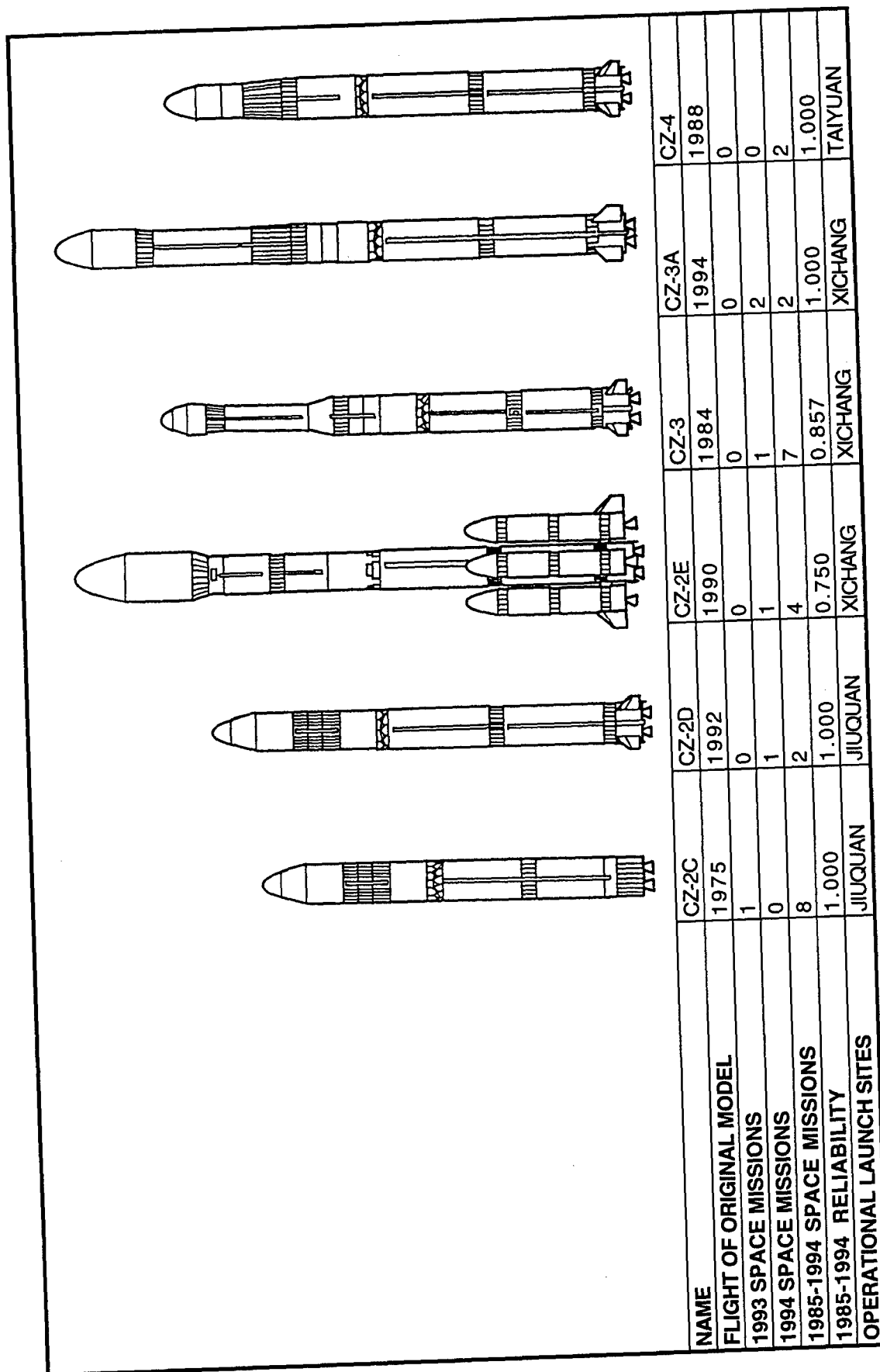


FIGURE 2.20 LONG MARCH LAUNCH VEHICLE VARIANTS.

of the CZ-3A is 6.5 metric tons (compared to 5.5 metric tons for the CZ-3) and the GTO payload capacity is 2.3 metric tons. Both 1994 flights of the CZ-3A were successful, although the payload of the second mission malfunctioned and could not reach its intended orbit.

Two more variants of the CZ-3 are scheduled to appear in the next few years. The CZ-3B is very similar to the CZ-3A but with four liquid-fuel strap-on boosters of the type used by the CZ-2E. This addition will nearly double the GTO payload capacity to 4.8 metric tons and provide a 12 metric ton capacity to LEO. The first flight of the CZ-3B will carry an INTELSAT spacecraft in late 1995 or early 1996. The CZ-3C will fill the gap between the CZ-3A and CZ-3B by using only two strap-on boosters, giving it a GTO payload capacity of 3.7 metric tons (References 159, 187-188).

The third currently operational series in the CZ family is the CZ-4 (also referred to as the CZ-4A) which to date has been employed only twice for inserting payloads into sun-synchronous orbits. Both flights in September of 1988 and 1990, respectively, lofted the PRC's first domestic meteorological satellite Feng Yun-1. The CZ-4 is a 3-stage launch vehicle carrying UDMH and nitrogen tetroxide for all stages. The CZ-4 first stage uses the same power plant as the CZ-3A but is nearly two meters taller. Likewise, the CZ-4 second stage is similar to that of the CZ-3A. The CZ-4 third stage is a specially designed unit powered by the YF-40 main engine. The payload capacity of the CZ-4 into a sun-synchronous orbit is cited as 2.5 metric tons (References 159, 189-190).

To satisfy the need for launching small satellites into LEO, the PRC is offering to make available the CZ-1D launch vehicle about 1995. The CZ-1 was the PRC's first space launch vehicle with missions in 1970 and 1971. Derived from the CSS-3 ballistic missile, the CZ-1 was quickly replaced by the more capable CZ-2 and its cousin the FB-1. The CZ-1D design consists of a 2-stage vehicle with the first stage burning UDMH and nitric acid whereas the second stage utilizes UDMH and nitrogen tetroxide. The payload capacity of the CZ-1D will be 900 kg to LEO and 300 kg to a sun-synchronous orbit (References 159-161, 191-192).

In the long-term the PRC has expressed the need to develop a much larger LEO payload

capacity: on the order of 25 metric tons. Such a capability is consistent with future plans for manned space systems, including a potential space station (Section 3.6). Even further into the future is the development of a fully reusable, two-stage-to-orbit space transportation system similar to the German Sanger concept. The PRC has been conducting detailed engineering studies in this area for more than a decade, but available resources have not permitted a commitment to begin development (References 159, 193-194).

Presently, the PRC operates three widely separated space launch centers to meet the needs of the entire CZ family of vehicles. Since these facilities are not located on the coast of China, each site is limited in the launch azimuths permitted which has led to separate centers for typical LEO, sun-synchronous, and GEO missions.

The oldest site which is used for low altitude posigrade missions with inclinations of 40° or more is called the Jiuquan Satellite Launch Center (sometimes referred to in the West as Shuang Cheng-Tzu) and is situated in the Gobi Desert in north central China. All CZ-2C and CZ-2D launches originate at Jiuquan. The second PRC space facility is the Xichang Satellite Launch Center which supports all GEO missions from its location in southern China. Separate launch pads support CZ-3 and CZ-2E operations. During 1993-1994 Xichang underwent extensive modernization and expansion, in part due to the requirements of the CZ-3A/B/C family and in part to meet commercial customer needs (References 195-197).

The Taiyuan Satellite Launch Center was commissioned for sun-synchronous missions and thus supports all CZ-4 launches. Taiyuan is located southwest of Beijing, and will support the Chinese-Brazilian Earth observation satellite program in 1996.

## **2.9 RUSSIAN FEDERATION**

During 1993-1994 the Russian Federation, the principal heir to the vast Soviet space program, conducted 97 space launches (down from 116 space launches during 1991-1992) with only three failures (Figure 2.21). By contrast, the rest of Eurasia undertook only 27 missions during this 2-year period and suffered three launch failures. Although one of the two operational CIS cosmodromes is in Kazakhstan,

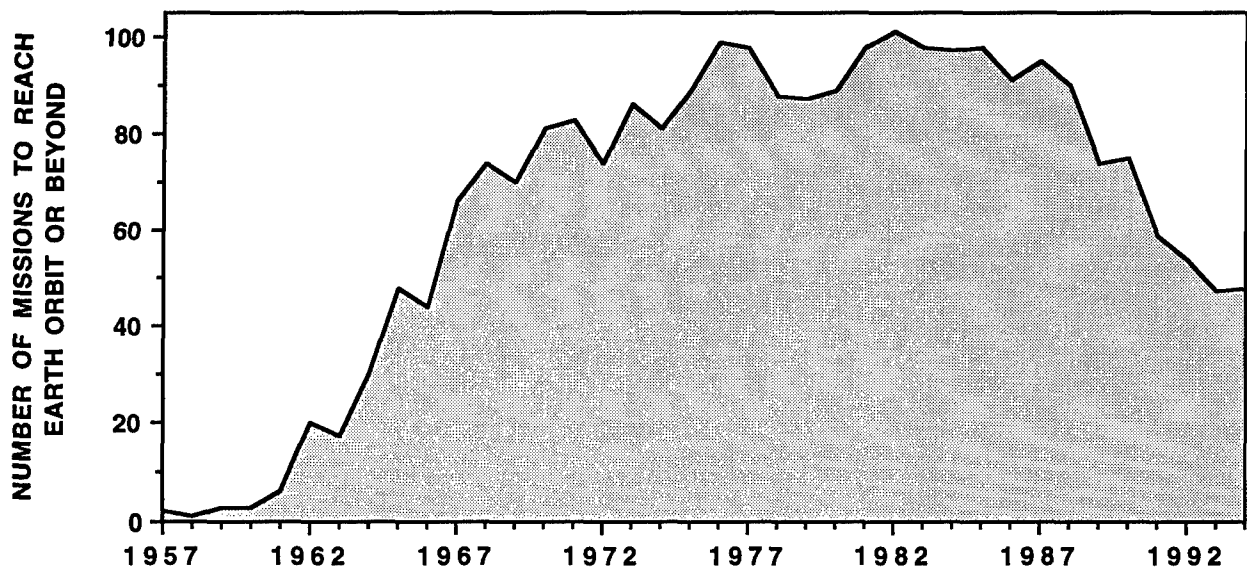


FIGURE 2.21 USSR/CIS SPACE MISSION RECORD.

the Russian Federation was responsible not only for launching all 1993-1994 launch vehicles but also for their payloads.

Two new launch vehicle types were added to the Russian arsenal in 1993-1994, which now consists of five basic families with seven major variants. By the end of the decade, the number of launch vehicle variants may double, and the new Svobodnyy Cosmodrome in the Russian Far East may be commissioned. A summary of Russian liquid-fuel main rocket engines is found in Table 2.2 (References 198-201).

### 2.9.1 Small Expendable Launch Vehicles

Until 1993 the smallest Russian launch vehicle in use was the Kosmos-3M booster, derived from the R-14 (NATO designator SS-5) medium range ballistic missile. Originally designed by the Yangel Design Bureau in Ukraine (now the Yuzhnoye [Southern] Design Bureau) and the Prikladnoi Mekhaniki (Applied Mechanics) Scientific Production Association in Russia, the Kosmos-3M has been manufactured by the Polet (Flight) Design Bureau for nearly 30 years. Eleven Kosmos-3M launches were conducted during 1993-1994, and all were successful.

The two-stage booster burns UDMH as a fuel and either nitric acid or N<sub>2</sub>O<sub>4</sub> as the oxidizer. The first stage employs two 11D614 (RD-216) main engines, while the second stage relies on a single, restartable 11D49 main engine. The second stage also carries an inde-

pendent propulsion system for coast and spacecraft deployment operations. Used only for LEO missions, the Kosmos-3M has a demonstrated payload capacity of 1,500 kg to a low altitude, 51°-inclination parking orbit. However, since 1988 all Kosmos-3M missions have originated from the Plesetsk Cosmodrome (Complexes 132 left and right and 133) with inclinations of 66° or more. The first commercial use of Kosmos-3M was scheduled for early 1995 when small American and Swedish spacecraft were to accompany a Russian navigation satellite into orbit. An improved model of the launch vehicle, the Kosmos-3MU (aka Vzlet), may begin operations by 1998 with a LEO payload capacity of 1.8 metric tons (References 202-205).

The two newest additions to the Russian launch vehicle stable come from the conversion of ballistic missiles declared excess following the START arms control agreements. The Start and Rokot launch vehicles are derived from the RS-12M (NATO designator SS-25) and RS-18 (NATO designator SS-19), respectively, and both flew maiden orbital missions during 1993-1994.

A consortium headed by the Kompleks Scientific and Technical Center has converted the RS-12M into a potentially mobile, 4- or 5-stage, low-capacity satellite launcher (Figure 2.24). The Start-1 variant, consisting of four solid-propellant stages (RS-12M plus a new fourth stage) with a maximum diameter of 1.8 m and a height of 22.7 m, was launched



NAME	START-1	ROKOT	KOSMOS-3M	MOLNIYA-M	SOYUZ-UU2	PROTON-K (3)	PROTON-K (4)
CIS DESIGNATOR (CURRENT)			11K65M	8K78M	11A511U/U2	8K82K	8K82K
US DESIGNATOR	SL-18	SL-19	SL-08	SL-06	SL-04	SL-13	SL-12
FLIGHT OF ORIGINAL MODEL	1993	1994	1964	1960	1966	1968	1967
1993 SPACE MISSIONS	1	0	6	8	17	0	6
1994 SPACE MISSIONS	0	1	5	3	15	0	13
1985-1994 SPACE MISSIONS	1	1	96	87	316	8	95
1985-1994 RELIABILITY	1.000	1.000	0.979	0.977	0.975	0.875	0.937
OPERATIONAL LAUNCH SITES	PLESETSK	BAIKONUR	PLESETSK	BAIKONUR, PLESETSK	BAIKONUR, PLESETSK	BAIKONUR	BAIKONUR

FIGURE 2.22 RUSSIAN OPERATIONAL LAUNCH VEHICLES.

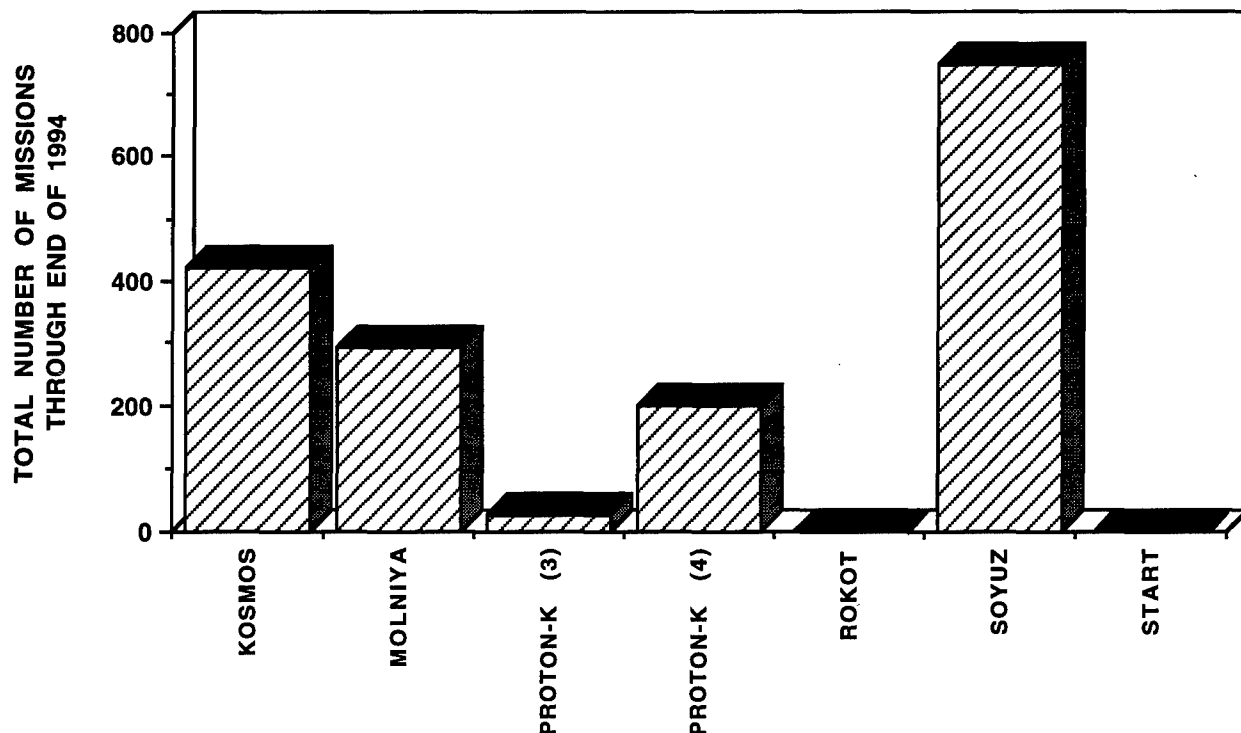


FIGURE 2.23 RUSSIAN LAUNCH VEHICLE UTILIZATION.

from the Plesetsk Cosmodrome on 25 March 1993 with a 225 kg payload. Start-1 has a LEO payload capacity of up to 550 kg. A 5-stage model, simply called Start, will employ two RS-12M second stages to increase the payload capacity to 850 kg and will be available by 1995. Both vehicles also carry a small liquid-propellant propulsion system to refine the final orbit. Although initial Start and Start-1 missions will be conducted from fixed Plesetsk facilities, future launchings from RS-12M road-mobile platforms are possible (Figure 2.25). Launch sites in Alaska and Australia have been considered (References 206-216).

Debuting in late 1994 was the Rokot launch vehicle developed by the Salyut Design Bureau of the Khrunichev State Space Research and Production Center. By adding a new liquid-propellant third stage Briz (Breeze) to the two-stage RS-18 ICBM, Russian aerospace engineers created a 2.5 m diameter, 24.6 m tall space launch vehicle with a LEO payload capacity of nearly 1.9 metric tons. All three stages burn UDMH and N<sub>2</sub>O<sub>4</sub>. Following two sub-orbital missions (20 November 1990 and 20 December 1991), Rokot finally launched an amateur radio satellite, Radio-ROSTO, into an orbit of 1,884 km by 2,161 km with an inclination

of 64.8° on 26 December 1994. Although the satellite deployment portion of the mission was successful, the Rokot third stage exploded a few hours after launch. This initial Rokot space mission originated from a silo at the Baikonur Cosmodrome (Site 175), but regular flights are envisioned from the Kosmos-3M facilities at the Plesetsk Cosmodrome starting in 1997 or from silos at the proposed Svobodnyy Cosmodrome as early as 1996. The German company Daimler-Benz Aerospace is teaming with Khrunichev to market Rokot commercially under the Eurokot Launch Services GmbH of Bremen (References 217-228).

Several other excess Russian ballistic missile types are being evaluated for launching small spacecraft into low altitude orbits. The Makeyev Design Bureau and State Rocket Center, located in the Chelyabinsk region of the Russian Federation, is trying to market space launch versions of its former submarine-launched ballistic missiles. Beginning in 1991 Makeyev began launching RSM-50 (NATO designator SS-N-18) missiles from Delta-IV submarines on short ballistic flights for commercial customers. Launches take place near Murmansk and are recovered near the Kamchatka peninsula.

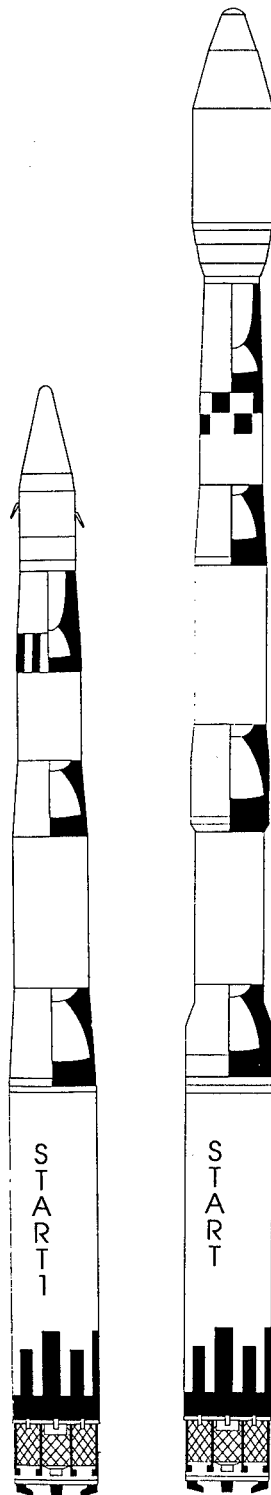


FIGURE 2.24 START-1 AND START LAUNCH VEHICLES.

Eventually, Makeyev hopes to introduce the liquid-propellant RSM-50 Volna and RSM-40 (NATO designator SS-N-8) Vysota space launch vehicles (Figure 2.26). The former, launched from either a Delta-III or Delta-IV sub-

marine, could carry payloads into LEO of up to 115 kg from equatorial sites. The Delta-I launched Vysota has about the same payload capacity but offers a smaller payload volume: 0.7 m<sup>3</sup> compared to 1.3 m<sup>3</sup> for Volna. The Shtil-1N, based on the liquid-fuel RSM-54 (NATO designator SS-N-23), could begin orbital flights with payloads of up to 510 kg in 1995 from the Severkosmos ground facilities at the Plesetsk Cosmodrome. The larger Shtil-3N would have an increased payload of 950 kg (References 229-233).

During 1993 the Makeyev Design Bureau and American investors examined the possibility to creating a new launch vehicle based on the RSM-54 and the RSM-52 (NATO designator SS-N-20). Called Surf, the launch vehicle would use the first stage of the RSM-52 solid-propellant booster topped with the four stages of the RSM-54. Rather than employing submarine or ground-level launch platforms,

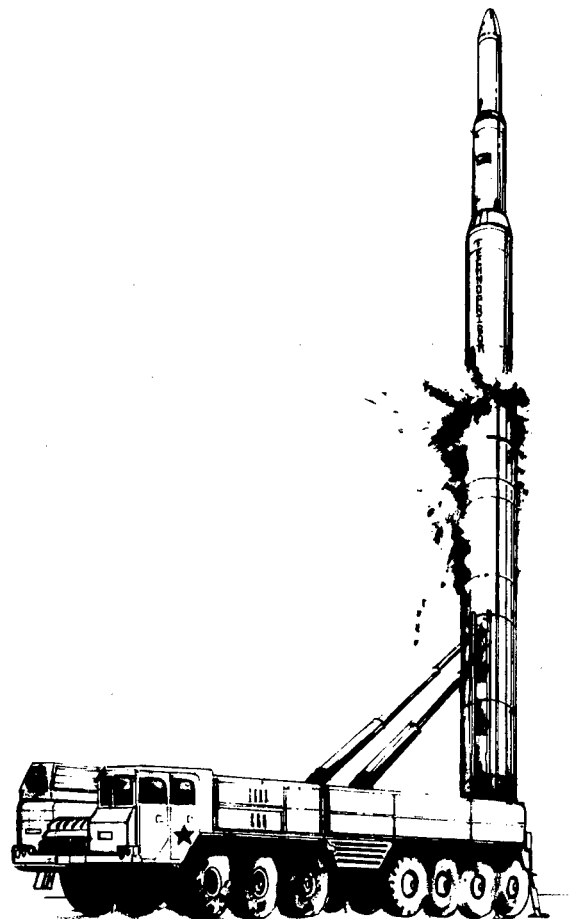


FIGURE 2.25 POTENTIAL START-1 LAUNCH PLATFORM.

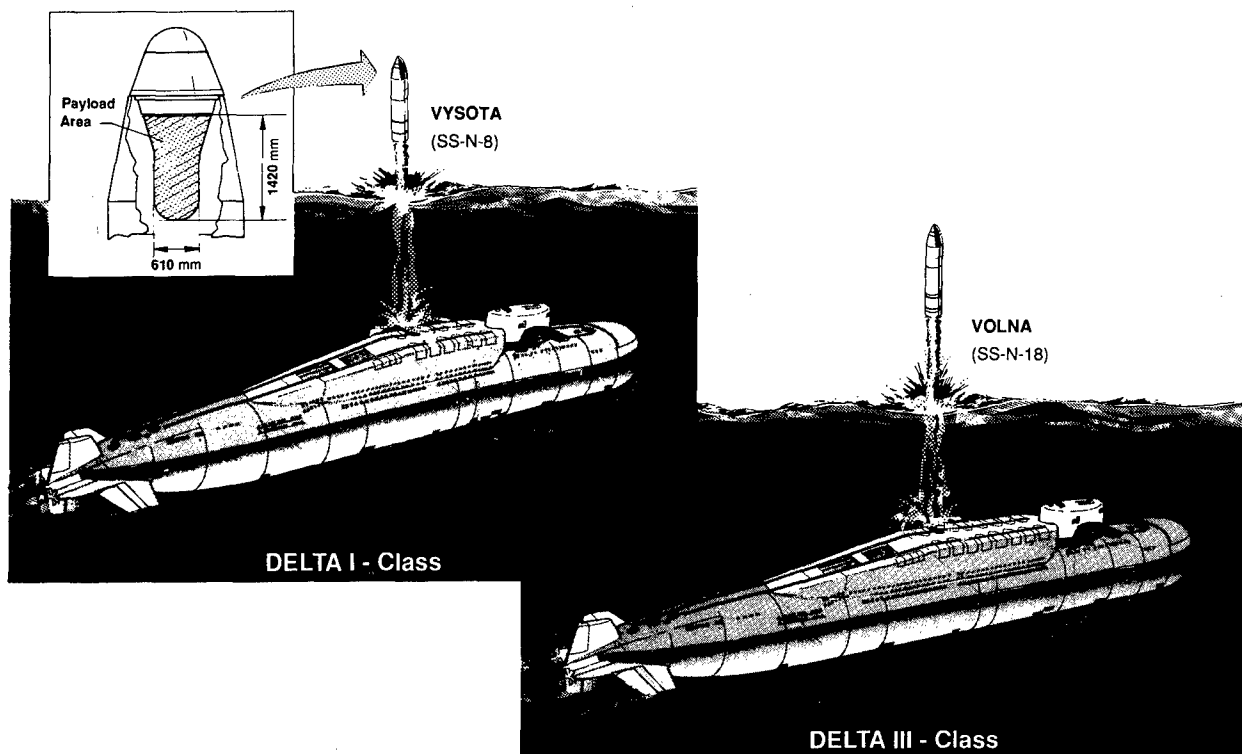


FIGURE 2.26 VYSOTA AND VOLNA SPACE LAUNCH SYSTEMS.

Surf would be launched in a floating condition on the surface of the sea and would provide a LEO payload capacity of 2.4 metric tons (References 234-240).

Finally, the Makeyev Design Bureau has also proposed developing the Aerokosmos air-launched space transportation system based on the Shtil-3A or RIF-MA launch vehicles. Using Il-76 MD, An-124, or An-225 cargo aircraft as launch platforms, the boosters would be carried internally, air-dropped, retarded by parachutes and then ignited. The Shtil-3A would have a LEO payload capacity of more than 600 kg, while the RIF-MA could carry nearly one metric ton (References 229, 232, 241).

A different air-launch concept was proposed by the Raduga Machine Building Design Bureau of Moscow in 1991. A Tu-160 strategic bomber would carry the Burlak missile under its fuselage for release at a high altitude and speed. The original Burlak design envisioned a payload capacity of 700 kg into equatorial orbits, but improvements were made by 1992 increasing the payload capacity to 1,100 kg. Later, the German space agency DARA joined the conceptual

studies, and the launcher name was changed to Diana-Burlak (References 242-244).

### 2.9.2 Medium Expendable Launch Vehicles

The most active Russian launch vehicle during 1993-1994 was the Soyuz-U (including the Soyuz-U2 variant). Derived from Sergei Korolev's original R-7 ICBM (NATO designator SS-6) and the subsequent Sputnik, Luna, Vostok, and Voskhod launch vehicles, the first Soyuz model was introduced in 1966 and has since been flown approximately 750 times in various configurations with a reliability of more than 97%. The two-and-one-half-stage launch vehicle burns simple liquid oxygen and a form of kerosene. The first stage consists of a core vehicle powered by a 11D512 (RD-108) main engine and four strap-on boosters with 11D511 (RD-107) main engines. The second stage carries a single, 4-nozzle 11D55 (RD-0110) main engine. The Soyuz-U/U2 launcher currently has a LEO payload capacity of approximately 7,300 kg for 52° inclination orbits. The Soyuz-U2 upgrade was introduced

in 1986 to support the Soyuz-TM spacecraft and has also been used for Progress-M spacecraft and the sixth generation photographic reconnaissance satellites.

Two Soyuz-U launch pads are operational at the Baikonur Cosmodrome (Complexes 1 and 31) and three are available at the Plesetsk Cosmodrome (Complexes 16 and 43 left and right). All Soyuz-U/U2 launch vehicles are produced by the Samara Central Specialized Design Bureau and Progress Plant with engines designed by the Energomash Scientific Production Association. Of the 32 missions flown during 1993-1994 only one failed. A malfunction in the second stage of the 27 April 1993 flight led to the loss of its photographic reconnaissance payload (References 245-246).

In 1991 work began on a major Soyuz improvement program. Now known as Rus, the modernized launch vehicle will have an increased payload capacity (up to 8,000 kg for a 52° orbit) with a new flight control system, enlarged payload fairings, and modified main engines. Operations are expected to begin at the Plesetsk Cosmodrome in 1997. Test firings of a new Rus main engine were already underway in 1994 (References 247-253).

The Molniya-M launch vehicle essentially consists of a basic Soyuz launch vehicle with an additional third stage. Like the lower stages, this third stage is powered by liquid oxygen and kerosene via a 11D33 main engine. Originally developed for lunar and planetary missions beginning in 1960, the Molniya-M is now used to place payloads of 1.6-1.8 metric tons into highly elliptical (~400 km by 40,000 km) Earth orbits inclined 63° to the equator. The upper stage and the payloads (normally a Molniya communications or Kosmos early warning satellite) are encased within the launch shroud and subsequently placed into a low altitude parking orbit by the lower stages. About half a revolution of the Earth later, the third stage is ignited for transfer into the elliptical orbit. During 1993-1994 eleven Molniya-M launch vehicles performed flawlessly, bringing the overall reliability to about 89% after nearly 300 missions. Molniya-M vehicles can be launched from either Baikonur or Plesetsk, but since 1990 the boosters have only operated from Plesetsk (Reference 254).

For several years, a modification of the Molniya-M launch vehicle has been under consideration. The third stage would be replaced by

a new Fregat stage which is derived from the main propulsion unit of the Phobos interplanetary spacecraft developed by the Lavochkin Scientific Production Association and launched in 1988. Tentatively designated Molniya-A, this launch vehicle would be capable of placing 5.4 metric tons into a sun-synchronous orbit. Introduction of the Molniya-A could come as early as 1996 (References 255-258).

### **2.9.3 Large Expendable Launch Vehicles**

The largest Russian launch vehicle in regular use is the Proton-K, used in a 3-stage configuration for heavy, LEO missions and in a 4-stage configuration for high altitude deployments. The former variant is capable of lifting 20-metric-ton-class spacecraft into very low altitude orbits of about 200 km, while the latter supports semi-synchronous (GLONASS), geosynchronous, and deep-space missions, such as lunar and planetary probes. Less than 30 3-stage models of the Proton-K have been launched since 1968 with an overall reliability of approximately 85%. On the other hand, the 4-stage model has flown nearly 200 times since 1967 with a reliability of nearly 87%. During the past 10 years (1985-1994) the combined reliabilities of all Proton-K launches has reached 93.2% (References 259-271).

The first three stages of the Proton-K were originally developed by the Chelomei Design Bureau in the early and mid-1960's. Today, design and production responsibilities lie with the Khrunichev State Space Research and Production Center in the Moscow region. All three stages burn UDMH and N2O4 hypergolic propellants. The first stage is powered by six 11D48 (RD-253) engines, the second stage by three 8D411K (RD-0210) engines and by one 8D412K (RD-0211) engine, and the third stage by a single 8D48 (RD-0212) engine. The first stage engines were developed by the Glushko Design Bureau (now the Energomash Scientific Production Association), whereas the Kosberg Design Bureau (now the Khimavtomatiki Design Bureau) created the second and third stage engines.

The fourth stage of the Proton-K is produced by the Energiya Rocket and Space Corporation (formerly the Korolev Design Bureau) and utilizes liquid oxygen and kerosene derivatives as propellants, much like the original Sputnik launch vehicle. The main engine is restartable and is known as the 11D58M (RD-

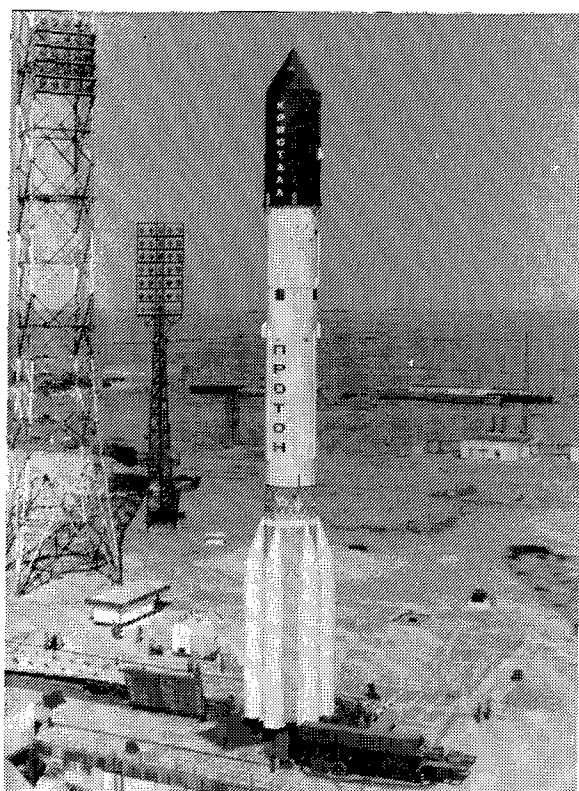


FIGURE 2.27 PROTON LAUNCH VEHICLE WITH MIR KRISTALL MODULE.

58M). The fourth stage comes in two major variants: the Block D without an independent navigation and guidance unit for deep-space missions and the Block DM with such a unit for most Earth orbital missions. Three models of the Block DM are now in use for semi-synchronous missions (11S861), for normal geosynchronous missions (11S86), and for heavy geosynchronous spacecraft (11S861-1). The last was first used in 1994 for the maiden flight of the Gals spacecraft.

During the 1993-1994 period no 3-stage versions of Proton-K were flown, but 19 flights of the 4-stage model were conducted. All were successful except the mission of 27 May 1993 which failed to achieve orbit due to propellant contamination in the second and third stages. The vehicle returned to flight the following September (References 259-276). Four launch pads for the Proton-K were built at Baikonur (Complexes 81 left and right and 200 left and right), but only two were operational at the end of 1994. The other two were undergoing major overhauls.

One of the principal topics concerning the Proton-K launch vehicle in recent years has been its entry into the international commercial

launch services market. An agreement between the US and the Russian Federation was finally reached in 1993 to allow limited use of Proton launch vehicles for commercial geosynchronous flights through the year 2000. In all, nine Proton missions to GEO (including the previously approved INMARSAT 3 contract) were allowed if the cost was not less than 7.5% below the international market value and no more than two missions were conducted in a 12-month period. Three LEO missions of US Iridium spacecraft were also permitted, but other LEO commercial contracts were subject to future negotiations and mutual agreement.

Marketing of Proton launch vehicles was to be handled via the newly formed Lockheed-Khrunichev-Energia joint venture. By the end of 1994 no commercial Proton launches had been undertaken, and the first such mission was unlikely before the spring of 1996. Meanwhile, debates concerning the raising of the number of GEO launches and how to count the leasing of Russian GEO spacecraft often became heated (References 277-286).

Before the US-Russian deal had been ironed out, Russian officials had already committed to a modernization of the nearly 30-year-old launch vehicle. The new Proton-KM launch vehicle will eventually be able to place 23.7 metric tons into LEO and 4.5 metric tons directly into GEO. With a standard Block DM fourth stage the Proton-KM will handle 3-metric-ton GEO payloads (compared to a 2.5-metric-ton limit for the Proton-K), but a new liquid oxygen/liquid hydrogen fourth stage will permit carrying the heavier 4.5-metric-ton spacecraft. In addition, new shrouds with larger volumes, some as large as 120 m<sup>3</sup>, will also be available.

Other elements of the modernization program include a new guidance system, more efficient energy and propellant management procedures, more benign payload launch environments, and more accurate landing zones for sub-orbital stages. Proton-KM will also be able to use a version of Khrunichev's new Breeze upper stage or Lavochkin's Fregat as an auxiliary fifth stage. Plans also call for replacing most Ukrainian suppliers of Proton components with new Russian vendors. The first Proton-KM may not fly until 1998 with the cryogenic upper stage variant not appearing before the year 2000. Tentative plans announced in 1992 to build Proton launch facilities at the Plesetsk Cosmodrome were later abandoned when a

program for a new generation heavy-lift booster was approved.

A competition to develop a successor to the Proton launch vehicle was underway during most of 1993-1994. The primary contenders were the proposed Energiya-M launch vehicle, already under development for several years, and a new design named Angara. With the cancellation of the Buran space shuttle program (see below) and the deferment of government sponsored super-heavy LEO and GEO spacecraft, the original 100-metric-ton-class Energiya launch vehicle program was halted, and efforts to develop the Energiya-M launch vehicle were redoubled.

Energiya-M would employ two standard Energiya strap-on boosters with one 11D520 (RD-170) engine each and a shorter central stage with only one 11D122 (RD-0120) engine (Figure 2.28). Upper stages and payloads would be stacked above the central stage within a large shroud. The Energiya-M could orbit LEO payloads of up to 35 metric tons or, using one of three upper stages, could provide GEO capabilities of 3.0, 4.5, or 7.0 metric tons, respectively (References 287-294).

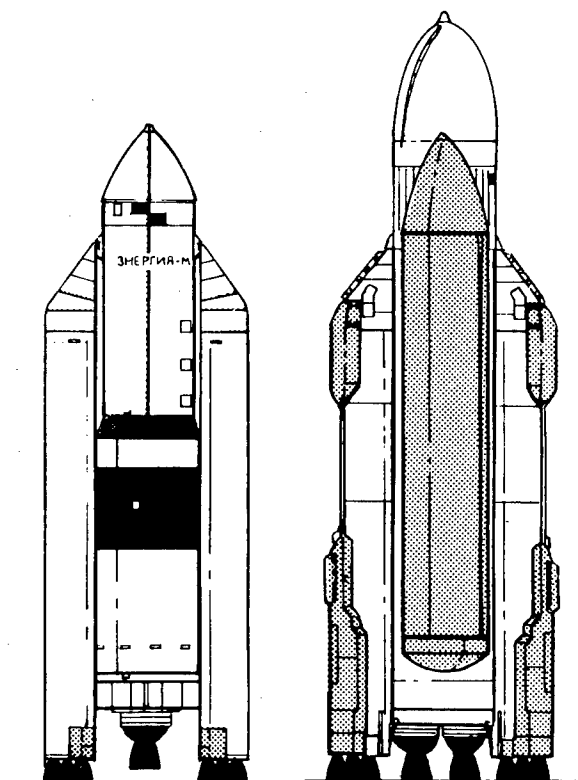


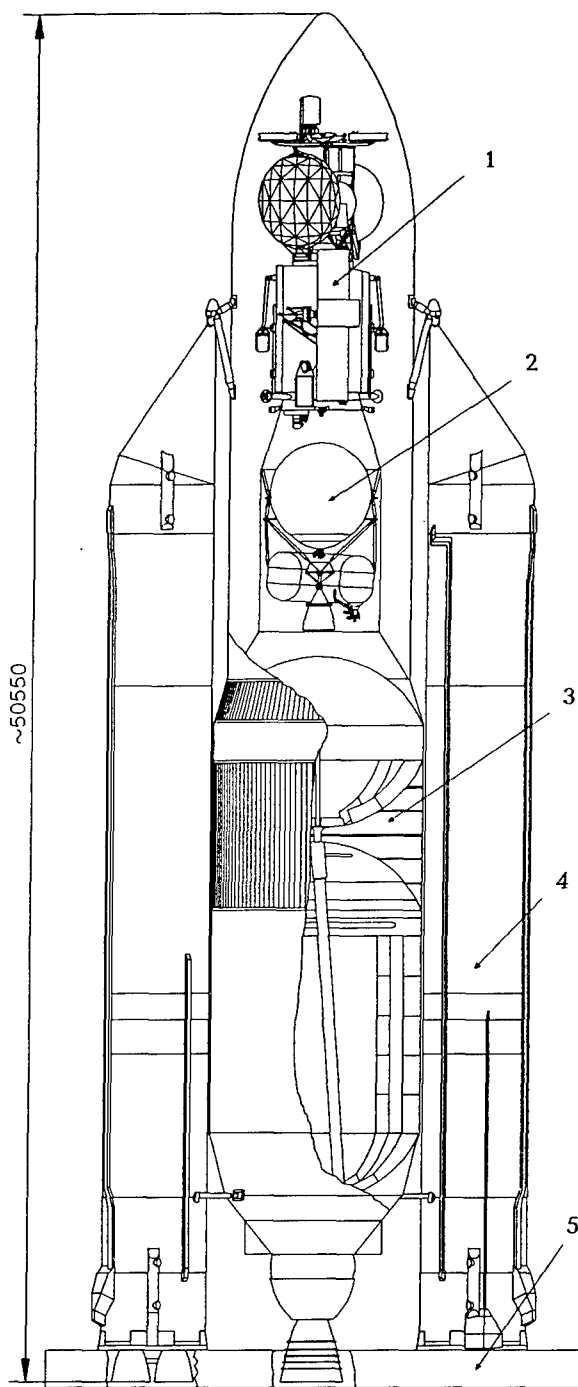
FIGURE 2.28 ENERGIYA-M AND ENERGIYA LAUNCH VEHICLES.

RKK Energiya's Energiya-M ultimately lost to Khrunichev's Angara launch vehicle. The odd-looking Angara (Figure 2.30) which could begin operations between 2000 and 2005, will have a LEO payload capacity of 26 metric tons, slightly more than the forthcoming Proton-KM. More importantly, Angara will consist of a liquid oxygen/kerosene first stage and a liquid oxygen/liquid hydrogen second stage, thereby avoiding the environmental concerns of Proton's hypergolic propellants. Angara's unusual configuration will also allow it to use the Zenit launch facilities now under construction at the Plesetsk Cosmodrome. No plans have been made to fly Angara from Baikonur, but eventually the launch vehicle could take advantage of the lower latitude (compared to Plesetsk) complexes at Svobodnyy. With an additional liquid oxygen/liquid hydrogen upper stage, Angara could place 4.5-metric-ton payloads into GEO, even from Plesetsk. Later, Angara's first stage may be made reusable (References 295-300).

#### 2.9.4 Reusable Launch Vehicles and Foreign Application of Russian Rocket Technology

About the time that Angara was selected to be the next heavy-lift Russian launch vehicle, the Central Research Institute of Machine Building was reportedly studying a concept for a partially reusable space transportation system. The 3-stage launch vehicle, named Norma, would use liquid oxygen and kerosene to power all main engines and would have a LEO payload capacity in excess of 75 metric tons. In the initial concept, stages 1 and 3 could be recovered and reused, employing many of the techniques envisioned for the advanced Energiya booster (Reference 301).

The Russian Federation's only large-scale reusable space transportation system was the Buran space shuttle, flown only once in 1988 in an unmanned mode (Figure 2.31). The Buran orbiter was quite similar to the US Space Shuttle with a mass of 75 metric tons, a payload capacity of 30 metric tons, a length of 36.4 m, and a wing-span of 24 m. Unlike the US Space Shuttle, Buran did not carry main engines which are employed during lift-off, since this function was performed by the Energiya launch vehicle central stage. During the early 1990's, a manned Buran spacecraft was being prepared for flight, but in 1993 the program was officially



1. Spacecraft
2. Space transfer vehicle
3. Central block
4. Side block
5. Launching/mating unit

FIGURE 2.29 ENERGIYA-M LAUNCH VEHICLE DETAILS.

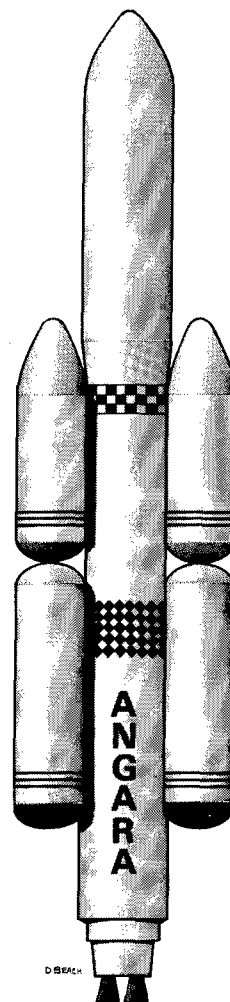


FIGURE 2.30 ANGARA LAUNCH VEHICLE.

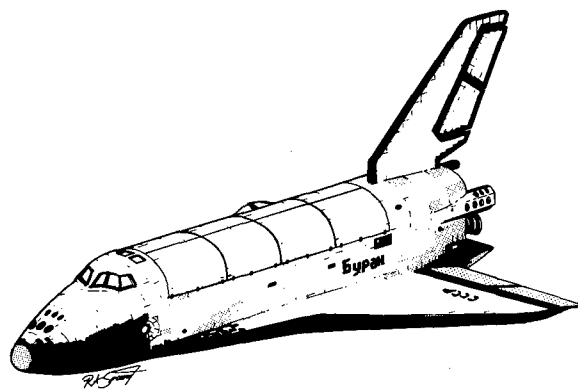


FIGURE 2.31 BURAN SPACE SHUTTLE.



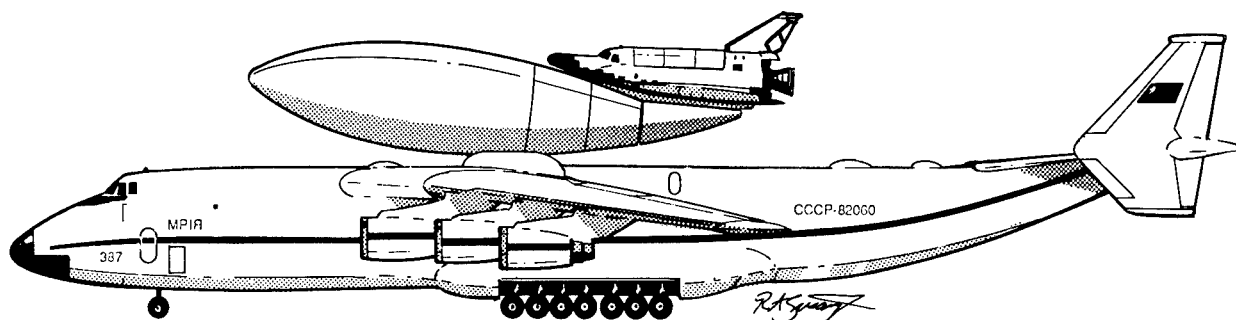


FIGURE 2.32 MAKS SPACEPLANE ON MODIFIED AN-225 CARRIER.

terminated. Much of the remaining Buran hardware has been mothballed and is in storage at the Baikonur Cosmodrome (References 302-310).

For several years a logical successor to the expensive Buran space shuttle has been the Multi-purpose Aerospace System (MAKS) based on a small spaceplane named Molniya and launched off the back of a modified An-225 aircraft (Figure 2.32). Conceived by the Molniya Scientific Production Association and the Zhukovskiy Central Aerohydro-dynamics Research Institute, MAKS is based on more than 30 years experience in developing reusable winged spacecraft under the Spiral, EPOS, BOR, and Buran programs. MAKS would be a 30-metric-ton-class spacecraft capable of manned (with a crew of two and an

8.3-metric-ton payload) or automated (with a 9.5-metric-ton payload) flight.

In the air-launched mode, the spaceplane and a large propellant tank would separate from the An-225 at an altitude of nearly 10 km, and the spaceplane, using tri-propellant (liquid oxygen/liquid hydrogen/ kerosene) RD-701 engines, would fly into a low altitude orbit. The overall dimensions of the spaceplane (Figure 2.33) are 19.3 m in length and 12.5 m wing-span. Despite considerable international interest in the program, no commitment has been made, and a maiden flight is unlikely in this decade (References 306, 311-324). Alternative plans to launch the Molniya spaceplane atop an Energiya-M launch vehicle died along with that booster program.

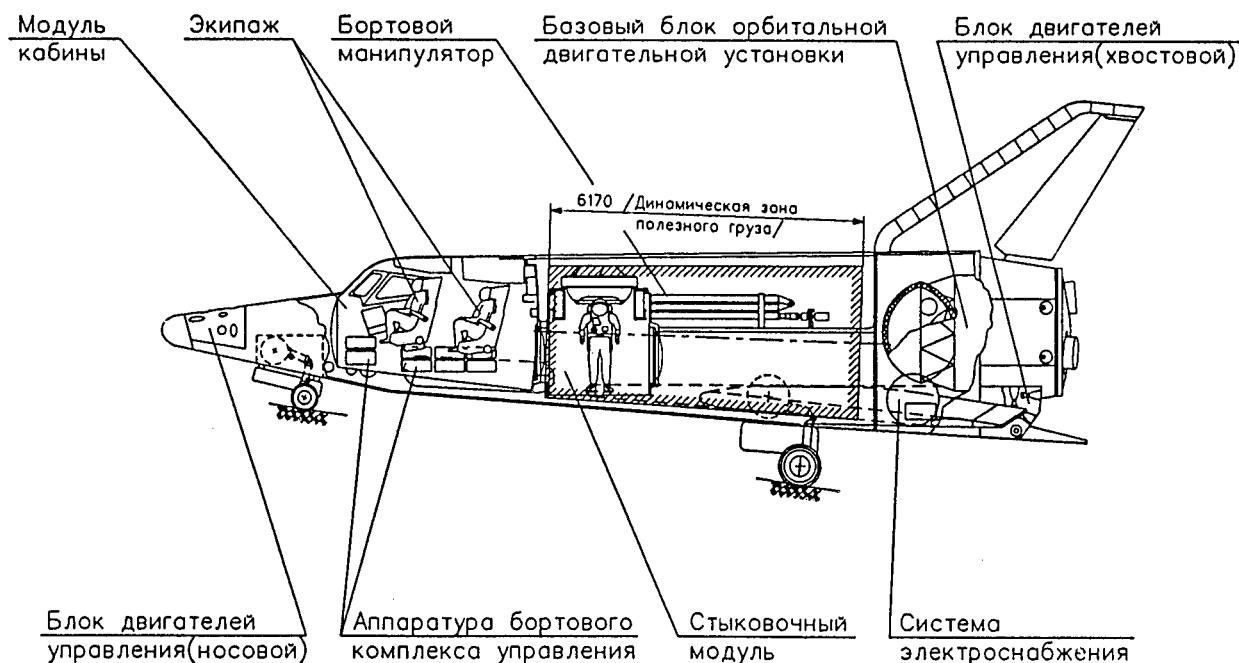


FIGURE 2.33 MAKS (MOLNIYA) SPACEPLANE.

In 1993 the Russian Space Agency initiated a research and development program named Orel to determine the feasibility of producing hypersonic engines to power a SSTO vehicle. Under the leadership of the Central Institute of Aviation Engine Building, scramjet evaluation testing began in November 1991 with the aid of S-200 tactical missiles launched from facilities near Baikonur. A second flight was conducted a year later with French assistance. Both missions tested the subsonic and supersonic (up to Mach 6) performance of the subscale, experimental engine. The near-term goal of the Orel program is to support a prototype SSTO designated the Tu-2000 which would have a take-off mass of 70-90 metric tons, a length of 55-60 m, a wing-span of 14 m, and would be able to carry a crew of two. The maiden flight of the Tu-2000 is not anticipated before the year 2010 (References 306, 321, 325-339).

Meanwhile, conventional Russian rocket engine technology (Table 2.2) has generated considerable international interest for new or improved expendable launch vehicles. The US firm Pratt & Whitney has teamed with the Energomash Scientific Production Association to market the RD-120, RD-170/RD-171, and

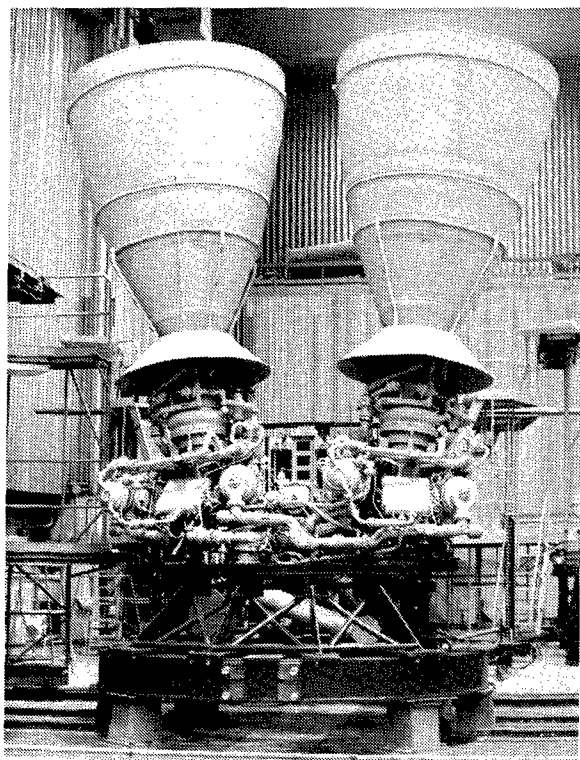


FIGURE 2.34 RD-701 TRI-PROPELLANT ENGINE.

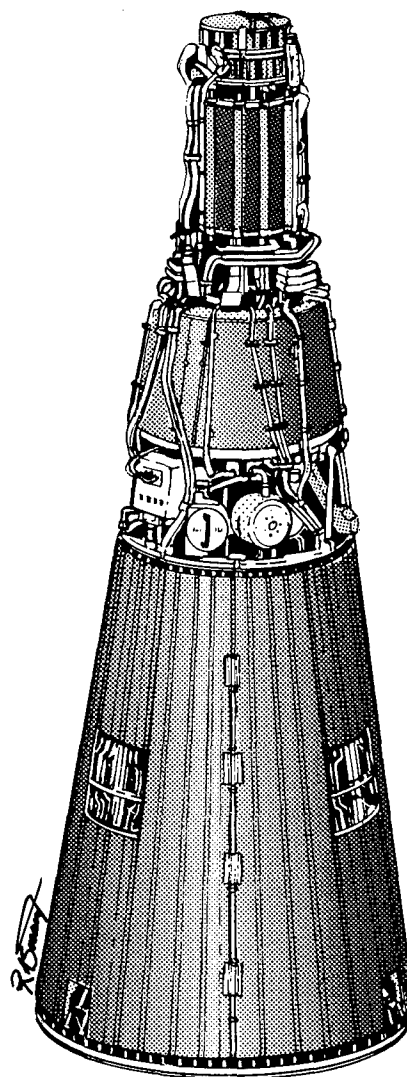


FIGURE 2.35 TOPAZ II NUCLEAR REACTOR.

RD-701/704 engines. A smaller, 2-nozzle version of the RD-170, called the RD-180, is under development and is being evaluated by Lockheed-Martin for possible use in the US Atlas launch vehicle. Not to be outdone, Aerojet is working with the Trud Scientific Production Association in Samara on adapting the 1960-1970's era NK-33 rocket engines (used for the ill-fated N-1 manned lunar launch vehicle) for use in the US.

Aerojet is also exploring applications of the Lyulka Engine Design Bureau's (Saturn Scientific Production Association) cryogenic D-57 engine and of the Khimavtomatiki Design Bureau's cryogenic RD-0120 flown by the Energiya launch vehicle. Energomash is also offering for commercial operations its small restartable RD-0161 liquid oxygen/ kerosene

engine. However, by the end of 1994 none of these activities had resulted in a firm decision to employ Russian rocket engine technology in Western launch vehicles (References 340-363). In 1993 reports did cite a clandestine sale of several RD-170 engines to the PRC (Reference 364).

Another Russian space propulsion specialty garnering wide attention in the West is the use of ion thrusters on spacecraft for attitude control and orbital adjustments. Often referred to as Hall thrusters, the low-power, high-endurance, high-efficiency engines produced by the Fakel Design Bureau have been in use on USSR/CIS LEO and GEO spacecraft since 1971. A joint Russian-American enterprise named International Space Technology, Inc. (ISTI) was formed to market engines such as the SPT-100. The principal partners of ISTI are Fakel, the Moscow Aviation Institute, and the US firm Loral. SEP of France joined the venture in 1993. In addition to substantial ground testing, ISTI has undertaken in-orbit test programs on both US and Russian spacecraft (References 365-375).

Finally, the USSR/CIS has studied the problem of designing nuclear-powered space propulsion for more than 30 years. Most concepts have involved the heating of a working fluid (e.g., liquid hydrogen) by a fission or fusion nuclear reactor. Although complex to build and operate, such nuclear-powered engines attain very high specific impulses (up to 950 seconds or more) and are considered an attractive means to send crews on interplanetary voyages. The principal organizations in the Russian Federation conducting research in this area are the Kurchatov Institute of Atomic Energy, the Research Institute for Thermal Processes, the Moscow Physical-Technical Institute, and the Luch Scientific Production Association. Testing of nuclear engine designs was performed for many years at the Semipalatinsk proving grounds. However, in recent years government support in both the Russian Federation and the West has declined significantly for space nuclear propulsion. A new concept for a nuclear-powered propulsion and electric power system, named Topaz-Star, was without funding in late 1994, and the simpler US-Russian Topaz II program was also faltering (References 376-388).

#### **2.9.5. Space Launch Facilities**

From 1966 to 1987 the USSR operated three launch sites: Baikonur in Kazakhstan and Plesetsk and Kapustin Yar in Russia. The last facility, which only launched the smallest space boosters, conducted its final orbital mission in 1987 and is no longer a part of the Russian Military Space Forces which manages all launch activities. Kapustin Yar's last space-related mission was the concluding sub-orbital flight of the BOR-5 subscale model of the Buran space shuttle in June, 1988. The other two sites remain quite active and both have performed more space launchings than any other facilities in the world.

The Baikonur Cosmodrome (also known as Tyuratam) is the oldest space launch facility in the world and by the end of 1994 had conducted over 1,000 space launches. Baikonur also supports the largest assortment of CIS launch vehicles: Proton-K, Rokot, Soyuz-U, Molniya-M, Tsyklon-2, and Zenit. Eight launch pads were operational in 1994, two were being overhauled, and three Energiya launch pads (complexes 110 left and right and 250) were no longer in use. Baikonur is the origin of all manned and man-related (e.g., space stations and resupply ships), lunar, interplanetary, high-altitude navigation, and GEO missions. Baikonur will also be critical for the deployment and the routine operations of the International Space Station. A total of 52 space launches were conducted at Baikonur in the 1993-1994 period, more than any other site in the world.

On 31 August 1991, soon after the attempted coup against the Soviet President Gorbachev, the President of Kazakhstan signed a decree asserting jurisdiction over Baikonur. The CIS agreement on Joint Activity in Space and Exploitation, signed at the creation of the CIS in Minsk on 30 December 1991, recognized the value of Baikonur and the need to maintain its facilities for the benefit of all CIS member states. However, the next three years witnessed considerable disagreement on how to effect this goal. Finally, in 1994 the Russian Federation and Kazakhstan concluded a leasing arrangement whereby Baikonur would come under control of the Russian Federation for an annual fee. The essential elements of the complex agreement are found in Section 7, space-related legal documents.

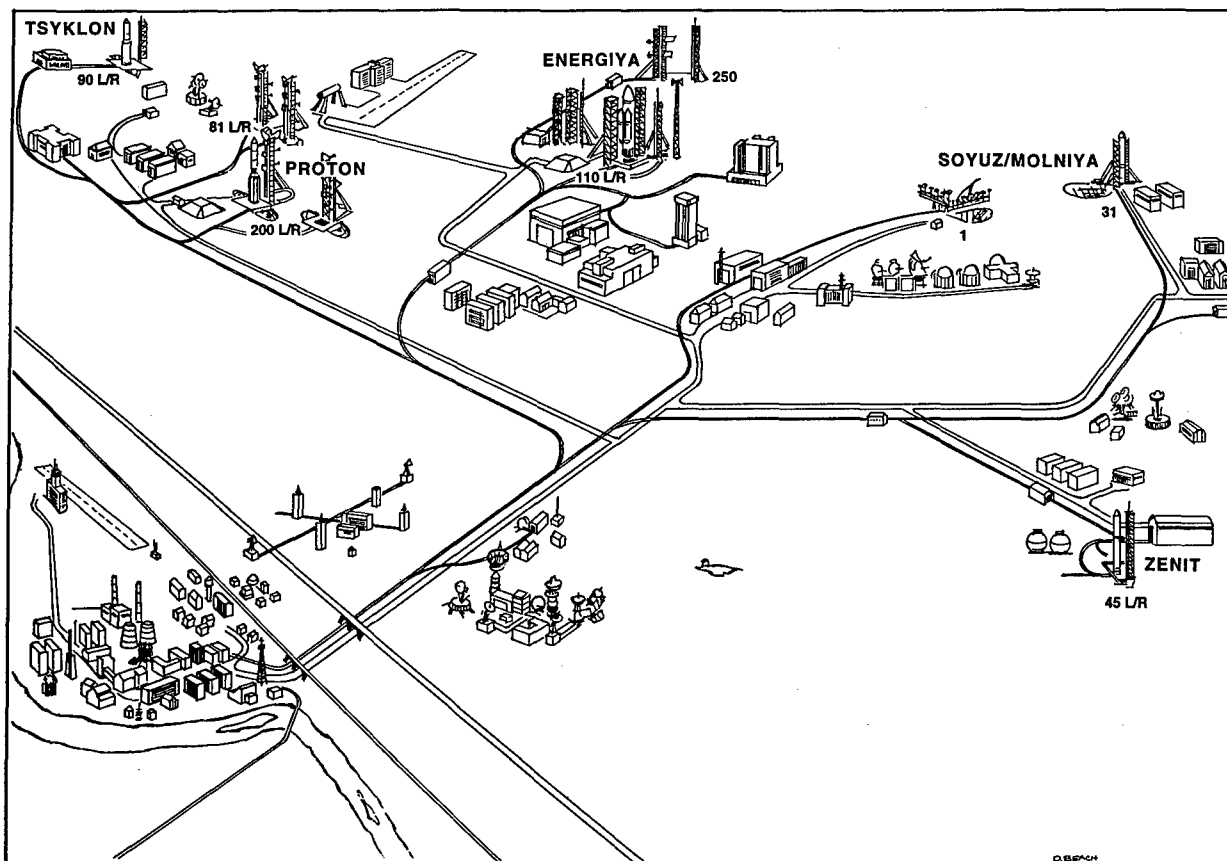


FIGURE 2.36 BAIKONUR COSMODROME.

During 1993-1994 world attention was fixed on the conditions at Baikonur and the adjacent town of Leninsk. Military unrest which led to riots in 1992 continued in 1993, and numerous Russian and Western reports warned of severe degradation of technical and social facilities. The Winter of 1993-1994 was particularly severe due to a shortage of food and heating, and launch delays and accidents (including a fire at an integration and test facility) occurred with disturbing frequency.

A US Congressional delegation visited Baikonur in December, 1993, to ascertain the extent of the problems and their potential impact on future US-Russian cooperative space missions. The situation stabilized in 1994 with the new Russian-Kazakhstan accord and direct intervention by the Russian government. In the short-term many military support activities will be transferred to the civilian Russian Space Agency, and in the long-term many space missions will likely be transferred to the Plesetsk Cosmodrome or the proposed Svobodnyy Cosmodrome (References 389-414).

The Plesetsk Cosmodrome, for many years (1969-1993) the busiest launch facility in the world, is located in northwestern Russia. Although capable of launching Korolev's R-7 ICBM beginning in 1960, Plesetsk did not perform its first space launch until 1966. By the end of 1994 more than 1,450 launchings had been conducted. From its northern latitude ( $\sim 63^{\circ}\text{N}$ ), space missions have been restricted to orbital inclinations between  $63^{\circ}$  and  $83^{\circ}$ . The  $1762\text{-km}^2$  cosmodrome is supported by the adjacent town of Mirny.

Currently, Plesetsk supports only four launch vehicle types: Kosmos-3M, Soyuz/Molniya, Tsyklon-3, and Start. Kosmos-3M can be launched from any of three launch pads (Complexes 132 left and right and 133). Soyuz/Molniya launch vehicles are supported by three active pads (Complexes 16 and 43 left and right), while a fourth pad (Complex 41) is in mothballs. The Tsyklon launch facilities include two active launch pads (Complexes 32 left and right). Start launches, which began in 1993, are conducted by the Strategic Missile Forces

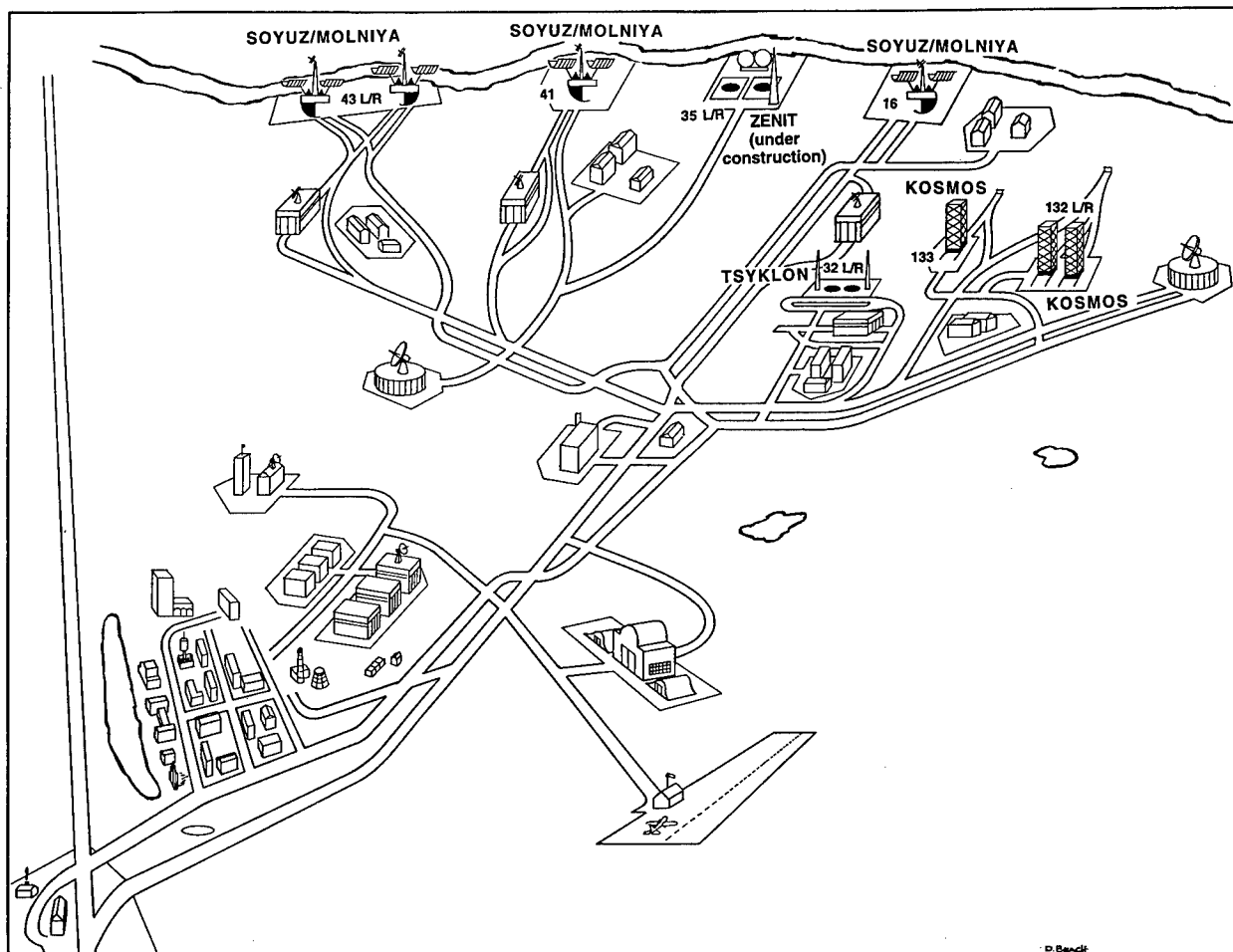


FIGURE 2.37 PLESETSK COSMODROME.

rather than the Military Space Forces from the fixed RS-12M launch facilities at site 158.

Construction was underway in 1994 on Complex 35 to permit Zenit launches by 1997. Eventually, the heavy-lift Angara launch vehicle may use this same complex. Later in the decade Rus and Rokot launches are expected from Plesetsk. Despite its important role in the Russian space program, not until 11 November 1994 was Plesetsk granted the title First State Testing Cosmodrome (References 415-422).

Unlike many space launch facilities in the world, both Baikonur and Plesetsk are not directly situated on or near a coast. Consequently, the lower, sub-orbital stages of USSR/CIS boosters normally fall back on former Soviet territory. This situation limits the permissible launch azimuths to avoid impacts near populated or foreign regions, e.g., due east launches (the most advantageous) from Baikonur are forbidden since lower rocket

stages would fall on Chinese territory. For those launch corridors which are used, tens of thousands of tons of spent boosters, many with toxic residual propellants still on board, now litter the countryside. Steps are underway around both Baikonur and Plesetsk to mitigate the situation, but the problem remains monumental.

Although officials for several years have talked about the advantages of constructing a new Russian cosmodrome in the Far East, not until early 1994 were specific plans set in motion. The selected site is a former ICBM base named Svobodnyy. Its latitude is essentially equivalent to the minimum orbital inclination now permitted from Baikonur. The first space launches from Svobodnyy, which could come as early as 1996, will be with Rokot boosters in modified silos. Proposals to operate the future Angara launch vehicle from Svobodnyy met initial resistance from the Russian government,

but the issue is apparently far from settled (References 423-430).

Finally, a consortium of joint stock companies, joint ventures, and state organizations created the Kosmoflot Scientific Technical Center to investigate the feasibility of deploying sea-based space launch facilities. These so-called floating cosmodromes would house the launch vehicles in partially submerged silos. The Okean system would be capable of handling boosters with payloads of up to two metric tons. A Government decree on 3 May 1994 designated RKK Energiya as the lead Russian industry to develop sea-based launch platforms. The decree also permitted cooperation with Ukrainian enterprises (References 431-434).

## **2.10 SPAIN**

In 1992 Spain's National Institute for Aerospace Technology (INTA) announced plans to develop a small orbital launch vehicle with a payload capacity of up to 100 kg into 600 km polar orbits. Named Capricornio, the launch vehicle is still in the preliminary design stage, although an initial flight in this decade is desired. To facilitate the development effort, INTA will produce the solid-propellant second-stage and purchase a foreign-made solid-propellant first stage. The third stage may be either foreign or domestic, liquid- or solid-fueled, although a foreign solid-propellant stage is the leading candidate. The initial launch site may be El Aranosillo near Portugal to be followed by a more capable launch facility in the Canary Islands. Despite funding reductions and schedule delays, the Capricornio program was still officially on-going at the end of 1994. Meanwhile, near-term launch needs for Spain's Minisat program will probably be met by the US' Pegasus or ESA's Ariane launch vehicles (References 115, 435-438).

## **2.11 SWEDEN**

Like its neighbor Norway, Sweden has suggested converting its sounding rocket range Esrange into a small space launch facility. During 1993 Sweden had joined Norway in offering a Polar Satellite Service with a yet-to-be-determined launch vehicle (Section 2.7). Later, Sweden leaned toward cooperation with the Russian Federation to meet potential commercial opportunities and its modest national orbital requirements. By the end of 1994, the

outlook for converting Esrange into a spaceport was poor (References 156-157, 439).

## **2.12 UKRAINE**

Although Ukraine has no domestic space launch facilities, the former Soviet republic has been producing high quality ballistic missiles and launch vehicles for more than 30 years. Its current offerings include the Tsyklon and Zenit launch vehicle families. Moreover, the Russian Kosmos-3M launch vehicle is derived from the Ukrainian R-14 ballistic missile. Ukraine also hopes to convert some of its other ballistic missiles into new small-capacity launch vehicles and continues to be a prime supplier of components for Russian launch vehicles. The heart of Ukrainian ballistic missile and launch vehicle expertise is the Uzhnoye (Southern) Scientific Production Association which evolved from the Yangel Design Bureau.

The Tsyklon family of launch vehicles is derived from Yuzhnoye's R-36 (NATO designator SS-9) ICBM and is used in two primary configurations. The two-stage Tsyklon-2 launch vehicle has been launched exclusively from the Baikonur Cosmodrome from Complex 90 left and right for high-value military missions: the co-orbital ASAT, RORSAT, EORSAT, and FOBS (Fractional Orbit Bombardment System). Only the EORSAT program is still operational; thus, the launch rate of the Tsyklon-2 is now only a few per year. Both stages employ hypergolic propellants, the first stage powered by three 11D69 (RD-218) engines and the second stage by one 11D26 (RD-219) engine.

The Tsyklon-3 launch vehicle appeared more than a decade after the Tsyklon-2 for use in both civilian and military space programs. The Tsyklon-3 is launched only from the Plesetsk Cosmodrome from Complex 32 left and right. The restartable third stage of the Tsyklon-3 is powered by the Ukrainian 11D25 (RD-861) which also uses UDMH and N<sub>2</sub>O<sub>4</sub>. A total of 11 Tsyklon-3 launch vehicles were flown during 1993-1994 with one failure occurring on 25 May 1994. The cause of that failure was determined to be a short circuit which prevented a successful separation of the second and third stages. Like its Baikonur cousin, the Tsyklon-3 can be transported to the launch pad, erected, fueled, and launched - all automatically and within only a few hours (References 440-444).

Ukraine's success with Tsyklon led to its selection as the lead for the Zenit medium-

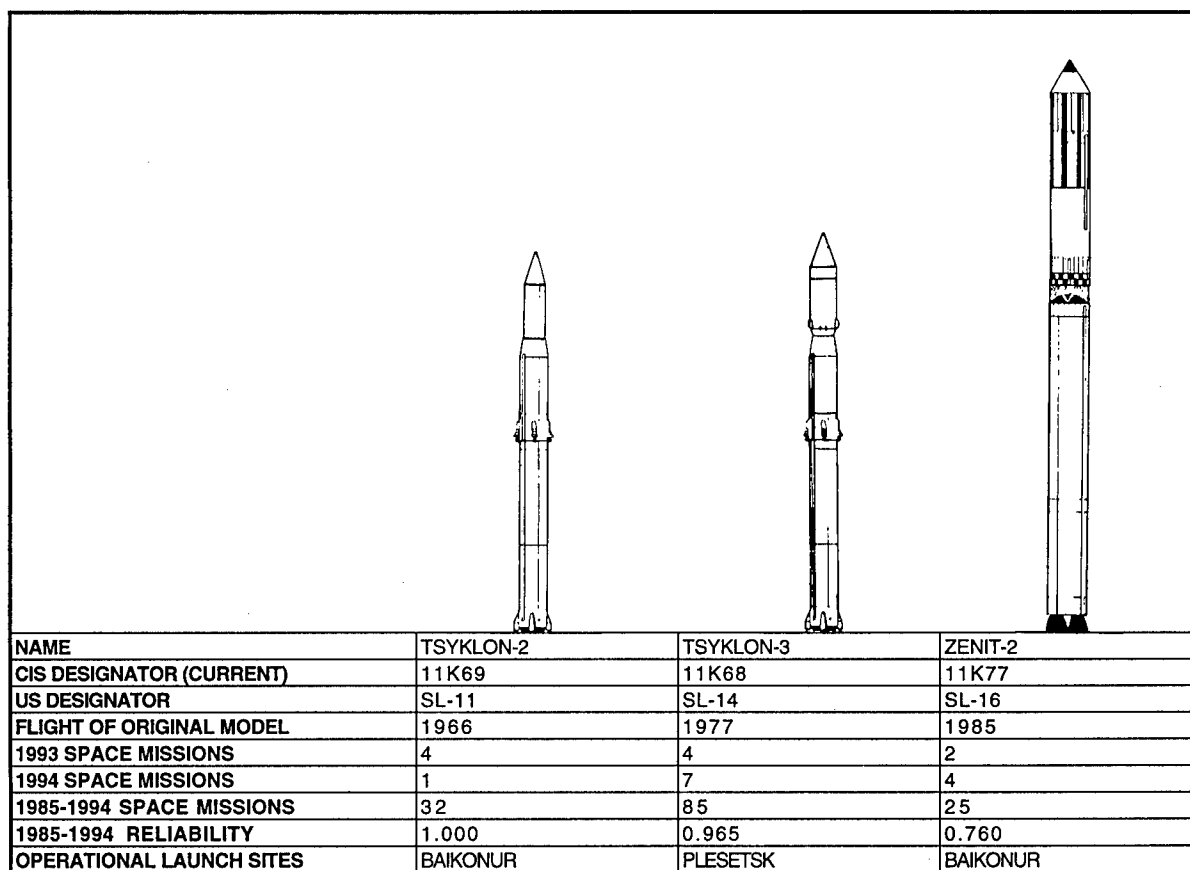


FIGURE 2.38 UKRAINIAN OPERATIONAL LAUNCH VEHICLES.

capacity launch vehicle in the second half of the 1970's. From its inception, the Zenit program was assigned a dual purpose: (1) develop a new low-cost, 15-metric-ton capacity launch vehicle and (2) design its first stage as a strap-on booster for the Energya heavy-lift launch vehicle. Although employing the more environmentally friendly liquid oxygen and kerosene as propellants, the Zenit adopted many of the attractive traits of the Tsyklon space transportation system. Zenit is highly automated and can be launched within hours of being erected on its launch pad (Figure 2.39).

Ukraine chose two Russian power plants to lift Zenit: the 11D521 (RD-171) engine for the first stage and the 11D123 (RD-120) engine for the second stage. Both were developed by the Energomash Scientific Production Association near Moscow. The Zenit was intended to replace the Soyuz-U launch vehicle for many programs, but economic and political forces combined to prevent Zenit from becoming a major part of the Russian space transportation infrastructure. Since its introduction in 1985, the

Zenit has primarily been used to support a single Russian military space program. However, Zenit picked up two new programs in 1994 and is slated to be one of the principal logistics links for the International Space Station (References 445-455). In addition, Zenit launch facilities at the Plesetsk Cosmodrome should be completed for launches beginning in 1997.

After a moderately successful initial flight period during 1985-1990 (three failures in 12 missions), Zenit encountered three successive failures, one of which destroyed its launch pad at Baikonur. The 4 October 1990 failure just seconds after launch was so severe that Complex 45 right had still not been repaired by the end of 1994. The launch vehicle successfully returned to flight in November 1992 and had not lost another payload through the end of 1994. A total of six missions were flown during 1993-1994. A small problem did arise following the 25 December 1992 and the 26 March 1993 flights. A modification to the second stage engine, which had caused launch failures in 1991 and 1992, led to an explosion of



FIGURE 2.39 ZENIT LAUNCH VEHICLE.

the stage within two days of launch. A subsequent fix resolved this problem (Reference 456).

Commercialization of the Zenit, once considered highly marketable, has been rife with numerous setbacks. An early concept to launch Zenits from the proposed Cape York, Australia, spaceport faded with the demise of that project. In 1993 a US firm, Commercial Space Management, signed an agreement with a Russian consortium for exclusive marketing rights for Zenit, but this deal, too, fell through when the US company went bankrupt (References 448, 457-480).

Later in 1994 a new marketing and operations arrangement was concluded by Yuzhnoye, the US Boeing Commercial Space Company, and the Norwegian ship-building firm of Kvaerner Group. The new venture, under the name of Sea Launch, envisions launching Zenit vehicles from floating platforms in the Pacific Ocean, perhaps as early as 1997. Meanwhile, Space Systems/Loral was considering the Zenit launch vehicle to deploy its Globalstar spacecraft. Those LEO missions would originate from the Baikonur Cosmodrome (References 461-463).

The ultimate success of the commercial Zenit remains dependent upon both technology and politics. For GEO missions a third stage must be added to Zenit. Already several years behind schedule, this effort has vacillated between accepting a modified Proton Block DM stage and developing a new Ukrainian stage. At the end of 1994, the former was assessed as the more likely outcome. Politically, disagreements (1) between Ukraine and the Russian Federation concerning the "nationality" of Zenit, (2) about the utilization of the Baikonur Cosmodrome, and (3) concerning Government approval for US spacecraft to be launched on Zenits still must be settled (References 464-470).

An air-launched version of Zenit, named Svitiaz, has also been proposed to circumvent the existing launch site problems, albeit at a significant penalty in payload capacity. Using the An-225 aircraft as a launch platform, a modified Zenit could deliver up to nine metric tons into LEO or one metric ton into GEO. A maiden flight of this configuration may be possible by 1998 (References 452 and 471).

Also by 1998 three new, small space launch vehicle systems could be in operation by Ukraine. The most powerful and the most imminent is the SS-18K, based on Yuzhnoye's large RS-20 (NATO designator SS-18) ICBM. Under the terms of the START accord, more than 150 RS-20 missiles must be removed from strategic service. Consequently, the designers and manufacturers of the 2-stage, liquid propellant (UDMH and N<sub>2</sub>O<sub>4</sub>) rocket have conceived of a space launch variant with a lift capacity of more than four metric tons into a LEO 65° inclination. Originally set for launch in 1993, the SS-18K had not risen from its Baikonur launch facility by the end of 1994 (Figure 2.40).

In its basic configuration for orbits below 500 km, the SS-18K would employ a third stage based on the Lavochkin Fregat stage. For payloads requiring orbital altitudes between 500 and 1,500 km, the Tsyklon C5M third stage could be carried in place of the Fregat stage. A third option would be to use a stage from Yuzhnoye's RS-22 (NATO designator SS-24) ballistic missile for payloads of 800 kg in orbits of 1,600 km and 90° inclinations. Mating a US solid-propellant upper stage with the SS-18K has also been proposed for missions to Mars. The SS-18K has been recommended for



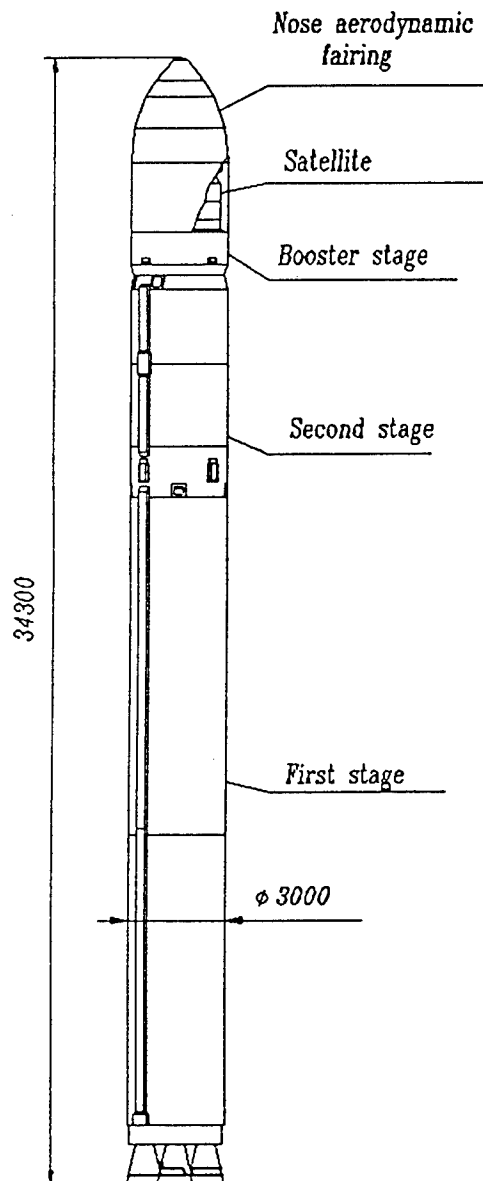


FIGURE 2.40 SS-18K LAUNCH VEHICLE.

conducting microgravity research in either orbital or ballistic regimes and for an emergency rescue service named VITA (References 472-477).

Another Yuzhnoye NPO product is the rail-mobile and silo-based RS-22 missile noted above. Ukraine is proposing to develop this solid-propellant missile into a 3- or 4-stage launch vehicle called Space Clipper with a low altitude, polar payload capacity of up to 1,750 kg or an equatorial GTO payload capacity of 800 kg. The booster would be carried aloft inside an An-124 cargo plane and then pushed out the rear cargo door at an altitude of approximately 10 km (Figure 2.41). A small parachute

would briefly stabilize the vehicle prior to first stage ignition (References 474, 478-480).

In 1994 Yuzhnoye and the French firm Dassault were reportedly exploring yet another family of small launch vehicles. Four variants of the launcher named Talisman would possess payload capacities of 250-750 kg for a 600 km, 90° inclination orbit. The boosters would use a small hypergolic (UDMH and N<sub>2</sub>O<sub>4</sub>) upper stage for final orbital insertion in addition to 2-3 solid-propellant lower stages.

The Space Clipper and the Sea Launch ventures noted above would provide Ukraine with more control over the launch of its space boosters. Other options under investigation are the use of a domestic floating platform in the Black Sea and the conversion of the Varyag aircraft carrier (References 482-484).

### 2.13 UNITED KINGDOM

During the 1960's and early 1970's the UK embarked on a national space launch program which culminated in the launch of the Prospero scientific satellite by a Black Arrow launch vehicle on 28 October 1971. However, for many years further UK interests in launch vehicle development were transferred to ELDO and ESA programs. Finally, in 1982 British Aerospace engineers originated a concept for a single-stage, horizontal take-off and landing (HOTOL) space transportation system. For the next several years the design was refined and eventually presented to ESA for consideration; meanwhile a 2-year proof-of-concept study was initiated in 1985 among the UK government, British Aerospace, and Rolls Royce.

Firm support for HOTOL never materialized from the UK government or ESA, but the project managed to survive at a very low level of effort. The baseline HOTOL design in the late 1980's called for a 250 metric ton unmanned vehicle which could deliver a payload of up to seven metric tons to LEO on a typical mission lasting 50 hours. The vehicle would be similar in size to the Concorde supersonic aircraft with an overall length of 62 m and wing-span of 28 m. Propulsion would be provided by four RB545 dual-mode engines which would operate in an air-breathing mode up to an altitude of 26 km where a conversion would be made to a liquid oxygen/liquid hydrogen rocket propulsion mode. A 14-year development program was recommended before HOTOL would become operational. Despite some modest Government

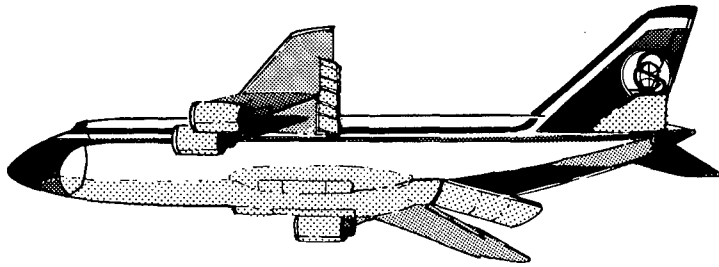
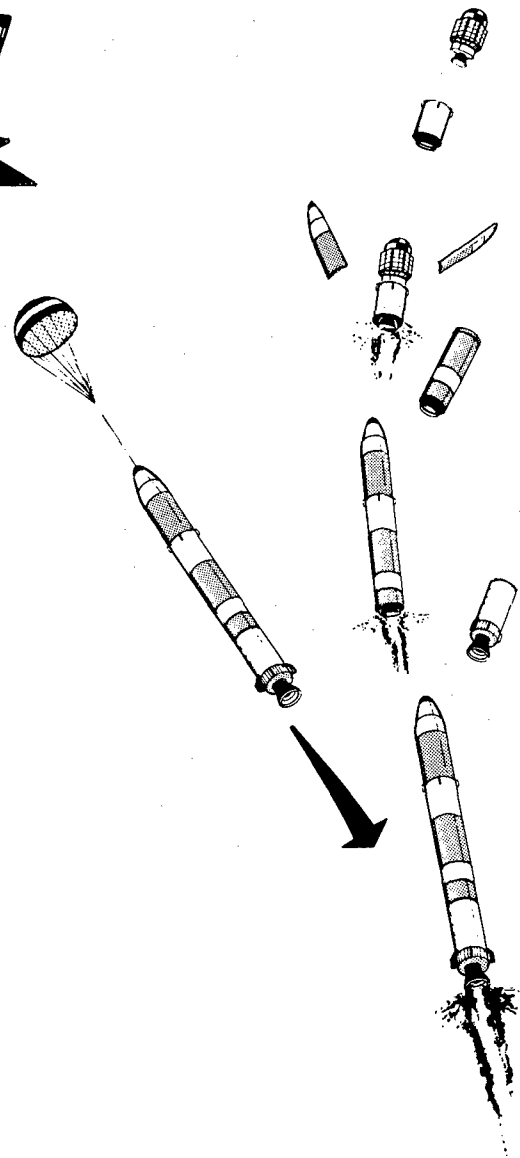


FIGURE 2.41 SPACE CLIPPER LAUNCH PROFILE.

encouragement to industry, the current prospects for a full-sized HOTOL project in this decade are poor (References 485-487).

In 1991 British Aerospace joined with the USSR's Antonov Design Bureau to consider the possibility of developing a smaller version of HOTOL, dubbed Interim HOTOL, which could be air-launched by a modified An-225 aircraft (Figure 2.42) Interim HOTOL would be released at an altitude of about nine kilometers and would then use four Russian RD-0120, liquid oxygen/liquid hydrogen engines to carry a payload of 7-8 metric tons into LEO. Wind tunnel testing of the Interim HOTOL and 8-engine Antonov carrier has been accomplished. The dimensions of Interim HOTOL are approximately 36 m length and 22 m wing-span. Despite considerable interest in the program, no full development plan has been approved and funded. The concept is still being evaluated and may be continued under ESA's FESTIP study activities (References 488-495).

In 1993 the British firm Reaction Engines, Ltd., revealed that it was developing an engine called SABRE which could propel a new spaceplane concept called Skylon. One of the founders of Reaction Engines was a principal in the design of HOTOL's unique power plant. Skylon would be 82 m in length with a wing-span of 27 m and could carry a payload of 10 metric tons to an orbit of 300 km at a 5° inclination (References 496-498).



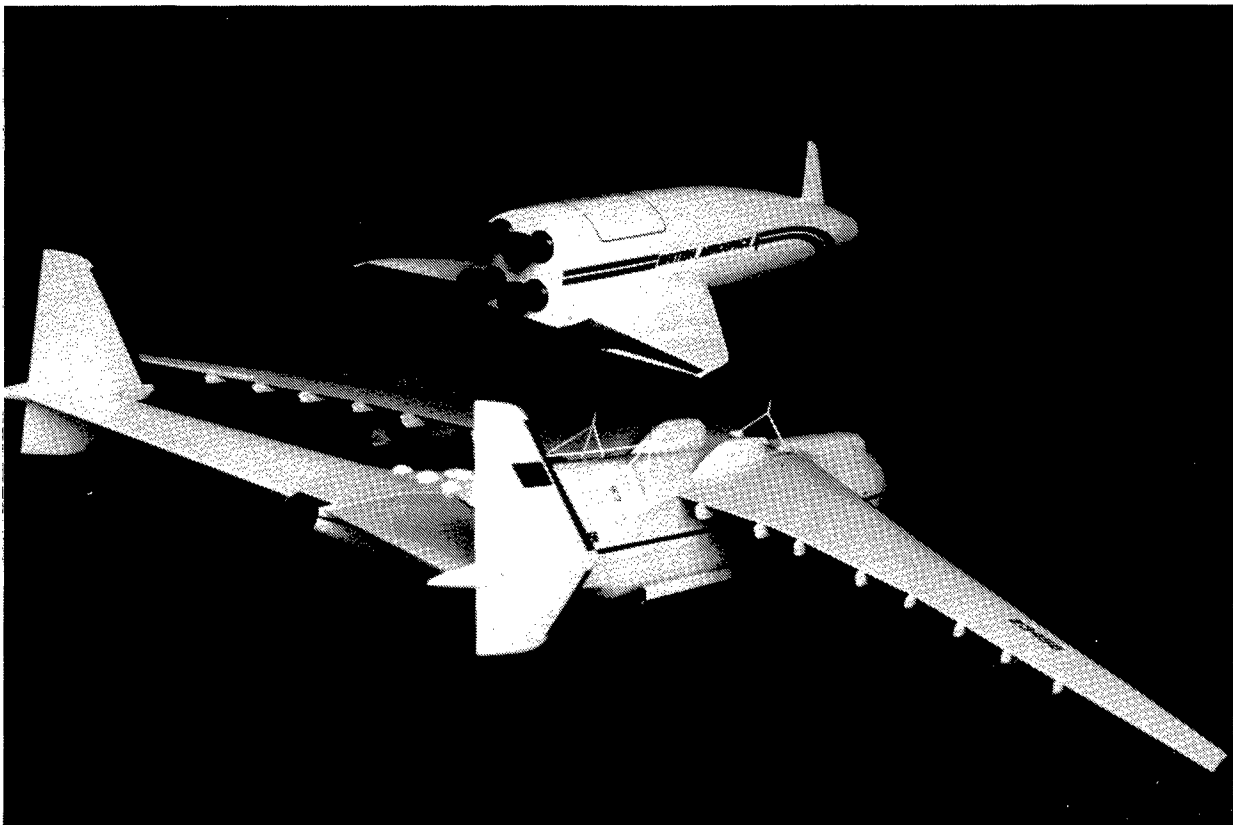


FIGURE 2.42 INTERIM-HOTOL ON MODIFIED AN-225 CARRIER.

## References - Section 2

1. Ariane 4, Arianespace, October 1983.
2. Reaching For The Skies, BR-42, ESA, 1988.
3. Ariane, "Space Special" by MBB Deutsche Aerospace, May 1991.
4. Ariane, Arianespace, May 1990.
5. "50th Ariane the First of a New Batch", Spaceflight, June 1992, p. 184.
6. P. B. de Selding, "Bigot Announces More Modifications for Ariane Launcher", Space News, 18-24 January 1993, p. 8.
7. "New Mission Procedure Proposed To Increase Ariane Performance", Aviation Week and Space Technology, 29 June 1992, p. 47.
8. P. B. de Selding, "Designers Had Flagged Suspect Ariane Component", Space News, 28 February - 6 March 1994, pp. 4, 21.
9. "Arianespace Aware of Bearing Problem", Space, May-June 1994, p. 38.
10. C. Covault, "Launch Failure Grounds Ariane", Aviation Week and Space Technology, 31 January 1994, pp. 27-28.
11. C. Lardier, "Coup d'Arret Apres l'Echec d'Ariane (V70)", Air & Cosmos, 9 December 1994, pp. 38-39.
12. C. Lardier, "Prochain Vol d'Ariane Fin Fevrier", Air & Cosmos, 6 January 1995, p. 62.
13. C. Covault, "Ariane Mission Review Cites Contamination Control", Aviation Week and Space Technology, 2 January 1995, pp. 58-59.
14. C. Covault, "Ariane Flights Halted to Examine Third Stage", Aviation Week and Space Technology, 12/19 December 1994, pp. 25-26.
15. Ariane 5 Programme, CNES and ESA, November 1990.
16. Ariane 5. Next Generation of Launchers, ESA, undated.
17. P. Donaldson, "Boosting Ariane 5", Space, May 1993, pp. 26-27.
18. H. Holsten, "Development Status of Ariane 5 Upper Stage", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 27-31.
19. P. Gil and F. Gastaldi, "The Ariane 5 Solid Propellant Motor", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 15-26.

20. M. Desloire et al, "Ariane 5 - A Launcher for the Next Decade", Paper IAF-93-V-1-600, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
21. C. Lardier, "A Un an Du Premier Vol d'Ariane 5", Air & Cosmos, 16 December 1994, pp. 24-25.
22. M. Senechal, "End of the String?", Space, March-April 1995, pp. 16-18.
23. "German Firm Delivers Test Model of Ariane's Speltra", Space News, 12-18 July 1993, p. 10.
24. "Speltra Payload Support Structure", Spaceflight, November 1993, p. 381.
25. "Ariane 5 Booster Firing Postponed", Aviation Week and Space Technology, 25 October 1993, p. 17.
26. P.B. de Selding, "Booster Test Bolsters Confidence in Ariane 5 Schedule", Space News, 27 June - 3 July 1994, p. 10.
27. "Arianespace Booster Stage Enters Qualification Testing", Space News, 10-16 October 1994, p. 12.
28. A. Borodulin, "Russian Parachutes Will Save the 'Ariane-5'. Contract Awarded in Preference to British and Americans Affords This Right", Moskovskiye Novosti, 18 July 1993, p. B7
29. M. Chernyshov, "Russian Parachute Makers Under Spanish-Dutch 'Roof'", Segodnya, 28 October 1993, p. 8.
30. "Ariane Managers Plan Recovery System Test", Space News, 27 June - 3 July 1994, p. 2.
31. C. Covault, "Ariane 5 'Battleship' Stage Fires on Kourou Pad", Aviation Week and Space Technology, 28 November 1994, pp. 65-66.
32. C. Covault, "Ariane 5 Engine Invigorates German Rocket Propulsion", Aviation Week and Space Technology, 20 February 1995, pp. 48-49.
33. "Ariane 5 Fairing Passes Ground Separation Test", Aviation Week and Space Technology, 28 November 1994, p. 66.
34. C. Covault, "CNES, Matra Accelerate Spacecraft, Ariane 5 Tests", Aviation Week and Space Technology, 5 December 1994, pp. 22-23.
35. "Arianespace Chief Bigot Projects 50 Year Life for Ariane 5", Space FAX Daily, 30 July 1993, p. 1.
36. P.B. de Selding, "Massive Ariane 5 Order Due", Space News, 9-15 January 1995, pp. 4, 21.
37. J.R. Asker, "Official Urges U.S. to License Ariane 5", Aviation Week and Space Technology, 10 April 1995, p. 66.
38. P.B. de Selding, "Builders Predict Ariane 5 Costs Will Exceed ESA Target", Space News, 8-14 November 1993, p. 11.

39. P.B. de Selding, "Europeans to Consider Modifying Ariane 5", Space News, 13-19 June 1994, p. 14.
40. P.B. de Selding, "Launcher's Development to Total About \$6.7 Billion", Space News, 19-25 December 1994, p. 7.
41. R. Hergott, S. Eury, and C.P. Ransom, "Ariane 5 Evolution", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 45-50.
42. I. Parker, "Growing Ariane 5", Space, August-September 1992, pp. 42-43.
43. "France Studies Ariane 5 Derivatives Comprising Family of Launch Vehicles", Aviation Week and Space Technology, 16/23 December 1991, p. 62.
44. "Ariane 5 Studied for Lunar Return", Aviation Week and Space Technology, 17 May 1993, p. 35.
45. P. B. de Selding, "French Signal Interest in Polar Orbit Launcher", Space News, 9-15 September 1991, p. 26.
46. M. Calabro and D. Jeannot, "Ariane Light Derivatives", Paper IAF 93.5.2.469, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
47. J.M. Astorg and C.P. Ransom, "The European Small Launcher", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 51-56.
48. P.B. de Selding, "European Firms Urge ESA to Build Small Launcher", Space News, 30 May - 12 June 1994, p. 4.
49. "Newsmaker Forum", Space News, 19-25 December 1994, p. 22)
50. H.A. Pfeffer, "Actions of ESA to Prepare for Future Space Transportation Systems", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 81-86.
51. B. Masse, "Reusable Rocket Launchers with Near Term Technologies", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 87-94.
52. P. B. de Selding, "Norway Plans to Bail Out of ESA Hermes Space Plane", Space News, 4-10 November 1991, p. 7.
53. P. B. de Selding, "ESA Mulls Drastic Alternatives to Hermes", Space News, 25-31 May 1992, p. 4.
54. "Hermes Demonstrator Proposed For Suborbital Flight in 2000", Aviation Week and Space Technology, 8 June 1992, p. 23.
55. P. B. de Selding, "ESA Proposes End To Costly Hermes Effort", Space News, 7-13 September 1992, pp. 1, 20 and P. B. de Selding, "Hermes' End Draws Outbursts in Parliament", Space News, 23-29 November 1992, p. 6.
56. P.B. de Selding, "Europe Drops Shuttle Effort", Space News, 27 September - 3 October 1993, pp. 1, 28.

57. Annual Report '93, ESA, May 1994.
58. Annual Report '94, ESA, June 1995.
59. "Europeans Begin Massive Renovation at Kourou Site", Space News, 22-28 February 1993, p. 13.
60. Interfax, Moscow, 12 October and 22 November 1994.
61. Reusable Space Transportation Systems. Reference Concept Sanger, MBB/Deutsche Aerospace, August 1992.
62. DARA Information 1991. Space Research for a Global Perspective, DARA, June 1991.
63. A Look at the Future, DLR, April 1991.
64. E. Hogenauer, "Hot Off the Runway", Space Technology International, 1989, pp. 114-115.
65. "International Cooperation in the Peaceful Uses of Outer Space: Activities of Member States - Germany", United Nations, A/AC-105/567/Add.3, 23 February 1994.
66. "Germans Pledge Support for Launch Vehicle Study", Space News, 15-28 November 1993, p. 17.
67. J. Spies, "The ADLER Vehicle Concept and Its Key Technologies", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 95-108.
68. J.M. Lenorovitz, "Germany's DARA Studies Russian Burlak Booster", Aviation Week and Space Technology, 27 June 1994, pp. 73-75.
69. N. Kidger, "India's SLV-3 Launch Vehicle", Spaceflight, February 1982, pp. 72-73.
70. Annual Report, ISRO Headquarters, Department of Space, Government of India, 1989 and previous years.
71. "Indian Launch Vehicle Accident Inquiry Focuses on Initial Stage Burn Sequence", Aviation Week and Space Technology, 24 October 1988, p. 47.
72. H.P. Mama, "India's Rocket Propellant Developments", Spaceflight, January 1995, p. 32.
73. Press release, Indian Space Research Organization, Department of Space, PPR:D:65:93, 22 September 1993.
74. A. Lawler and V. Raghuvanshi, "India's Rocket Effort Falters", Space News, 27 September - 3 October 1993, pp. 1, 28.
75. S. Verma, "Software Error Blamed for Crash of Indian Rocket", UPI, New Delhi, 3 January 1994.
76. C. Covault, "India Launches New Booster", Aviation Week and Space Technology, 24 October 1994, p. 24.

77. V. Raghuvanshi, "India Sets Sights on Launch Market as PSLV Flight Succeeds", Space News, 24-30 October 1994, p. 9.
78. All-India Radio, New Delhi, 29 October 1994.
79. All-India Doordarshan Television, New Delhi, 7 December 1994.
80. C. Lardier and V. Raghuvanshi, "Le PSLV Interesse Les Militaires Indiens", Air & Cosmos, 28 October 1994, p. 35.
81. T. Pirard, "India Develops Cryogenic Engine", Spaceflight, February 1988, p. 54.
82. All-India Radio, 31 August 1992.
83. "GLAVKOSMOS Sternly Rebukes U.S. Allegations As Protectionist", European Space Report, 16 June 1992, pp. 1-2.
84. A. Lawler, "India's Plan To Buy Russian Stage Draws U.S. Protests", Space News, 27 April-3 May 1992, p. 36.
85. Krasnaya Zvezda, 16 June 1992, p. 2.
86. Izvestiya, 21 April 1992, p. 5.
87. "Russian Sale of Rocket Engine To India", U.S. Department of State public release, 11 May 1992.
88. ITAR-TASS, Moscow, 25 June 1992.
89. V. Raghuvanshi, "Yeltsin: Cryogenic Rocket Deal Is Irrevocable", Space News, 1-7 February 1993, p. 6.
90. ITAR-TASS, Moscow, 26 June 1995.
91. "India Increases Order for Cryogenic Engines", Space News, 13-19 March 1995, p. 2.
92. V. Raghuvanshi, "Russia, India Discuss Cryogenic Contract", Space News, 15-28 November 1993, p. 6.
93. A. Lawler and V. Raghuvanshi, "U.S. Sanctions Against Russia, India To Expire", Space News, 2-8 May 1994, pp. 3, 28.
94. V. Naumov, "Fate of Cosmic Deal", Rossiyskiye Vesti, 4 January 1994, p. 6.
95. V. Raghuvanshi, "Indian Officials Debate Indigenous Cryogenic Effort", Space News, 2-8 August 1993, p. 17.
96. "U.S., Russia Settle Export Disagreement", Aviation Week and Space Technology, 26 July 1993, p. 27.
97. All-India Radio, 25 January 1993.



98. V. Raghuvanshi, "Indians Test Air-Breathing Engine", Space News 22-28 February 1993, p. 7.
99. J. Simpson et al, "The Israeli Satellite Launch", Space Policy, May 1989, pp. 117-128.
100. C. Covault, "Israeli Rocket Proposed to NASA For U.S. Commercial Booster Project", Aviation Week and Space Technology, 1 October 1990, pp. 100-101.
101. S. Fisher, "Israel Joins Up", Space, January-February 1991, pp. 12-14.
102. "Atlantic Research Corporation and Rafael in Israel Announce Cooperative Effort on AUS-51", news release by ARC and Rafael, Virginia, 2 September 1992.
103. "IAI Space Activity Accelerates", Israel Space Research and Technology Information Bulletin, Vol. 7, No. 1, pp. 4-5.
104. C. Covault, "IAF Highlights New Israeli Booster", Aviation Week and Space Technology, 17 October 1994, p. 25.
105. P.B. de Selding, "ISA Petitions for Boost in Budget", Space News, 17-23 October 1994, p. 8.
106. T. Pirard, "Israel Invests in Space Technology", Spaceflight, April 1994, p. 121.
107. "Italy Bets on Bantamweight Carina", Space News, 9-15 July 1990, p. 2.
108. S. Coleden, "Upgraded Scout Booster Readied To Begin Tests Again", Space News, 22 June-5 July 1992, p. 24.
109. R. Riccitiello, "Italian Lawsuit Centers On Scout", Space News, 2-8 November 1992, p. 3.
110. A. Lawler, "Export Licenses May Be Too Late for U.S. Firms", Space News, 11-17 January 1993, p. 4.
111. R. Riccitiello, "Court Ruling Leaves Italy With Two Scout Programs", Space News, 18-24 January 1993, pp. 3, 21.
112. R. Riccitiello, "ASI Pays First Installment, Scout's Future Still Uncertain", Space News, 8-14 March 1993, p. 9.
113. "Newsmaker Forum", Space News, 31 July - 6 August 1995, p. 22.
114. R. Riccitiello, "Plans Falter for Joint U.S.-Italian Scout", Space News, 2-8 August 1993, pp. 4, 20.
115. P.B. de Selding, "Italy's BPD To Start Small Rocket Effort", Space News, 5-11 June 1995, pp. 3, 29.
116. Space In Japan 1988-89, Research and Development Bureau, Science and Technology Agency, Tokyo, 1988.
117. M. Oda and Y. Tanaka, "Japan's Blossoming Space Science", Sky and Telescope, January 1987, pp. 7-11.

118. C. Covault, "Japan Designing Atlas-Class Rocket To Launch Lunar, Planetary Missions", Aviation Week and Space Technology, 20 August 1990, pp. 63-68.
119. K. P. Dawson, "Japanese M-5 Faces Delay to '95 Start", Space News, 15-21 June 1992, p. 4.
120. "Japan Presses on With M-5 Project Despite Motor Casing Problems", Aviation Week and Space Technology, 10 August 1992, pp. 48-49.
121. J. Onoda et al, "Structural Development Status of Japanese Next Generation Launcher for Scientific Satellites", Paper IAF-93-I.2.208, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
122. Kyodo News Service, Tokyo, 21 June 1994.
123. E. Sekigawa, "Japan Confirms Delays in M-5 Booster Launch", Aviation Week and Space Technology, 27 June 1994, p. 82.
124. M. Mecham, "Japan's Launch Capacity to Grow with J-1, M-5", Aviation Week and Space Technology, 20 March 1995, pp. 57-58.
125. NASDA. National Space Agency of Japan, NASDA, 1994.
126. H-II Launch Vehicle, NASDA, 1994.
127. R. Nagao, "Development Status of the LE-7 Engine", Paper IAF-93-470, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
128. T.S. Sienko, "Lift-off at Dawn", Space, March-April 1994, pp. 6-8.
129. N.W. Davis, "Japan's Space Hopes Ride on H-II", Aerospace America, March 1994, pp. 36-40.
130. E. Sekigawa, "Kawasaki Completes Design of New H-2 Payload Fairings", Aviation Week and Space Technology, 18 April 1994, p. 56.
131. E. Sekigawa, "High H-2 Cost Worries NASDA", Aviation Week and Space technology, 19 July 1993, p. 66.
132. M. Mecham, "Japan Space Programs Keyed to H-2 Success", Aviation Week and Space Technology, 31 January 1994, pp. 50-51.
133. "H-2 Commercial Use Limited by High Costs", Aviation Week and Space Technology, 31 January 1994, p. 52.
134. H-II Rocket, NASDA, undated.
135. J-I Launch Vehicle, NASDA, 1994.
136. N. Saki, et al, "System Concept of J-I Launch Vehicle", 5th International Space Conference of Pacific Basin Societies, 6-9 June 1993.

137. "New Japanese Booster", Aviation Week and Space Technology, 19 August 1991, p. 11.
138. K. P. Dawson, "NASDA Seeks To Fund New Launcher in 1992 Request", Space News, 9-15 September 1991, p. 21.
139. P. Proctor, "Japan To Offer J-1 Solid Rocket For Launch of Small Payloads", Aviation Week and Space Technology, 10 August 1992, pp. 47-48.
140. S. Mansfield, "Japanese Panel Pushes Space Plane Project", Space News, 26 July - 1 August 1993, p. 6.
141. E. Sekigawa, "Renewed Backing for Japan's HOPE", Aviation Week and Space Technology, 2 August 1993, p. 65.
142. ITAR-TASS, Moscow, 20 February 1995.
143. S. Mansfield, "Japan To Test Hope", Space News, 16-22 January 1995, p. 18.
144. "NASDA Sets HOPE Tests", Aviation Week and Space Technology, 20 March 1995, p. 58.
145. H-II Orbiting Plane (HOPE), technical brochure issued by NASDA, T1991.
146. K. P. Dawson, "Japan's Space Plane Faces Termination or Shrinking", Space News, 23-29 November 1992, pp. 3, 20.
147. "Japanese Give Details on Ryusei Reentry", Military Space, 3 October 1994, pp. 8-9.
148. "First H-2 Payload Aids HOPE Shuttle", Aviation Week and Space Technology, 31 January 1994, p. 53.
149. "Space Agency Considers Doubling Size of HOPE Unmanned Space Vehicle", Aviation Week and Space Technology, 13 August 1990, pp. 65-68.
150. S. Mansfield, "Commission To Endorse Key NASDA Projects", Space News, 11-17 July 1994, p. 3.
151. S. Mansfield, "Japanese Outline Space Vision", Space News, 1-7 August 1994, p. 8.
152. E. Sekigawa, "Japan To Stress Reusable Vehicles", Aviation Week and Space Technology, 8 August 1994, pp. 64-65.
153. I. Parker, "Take-Off From Andoya", Space, April 1993, pp. 14-15.
154. I. Parker, "Scandinavia in Space", Space, April 1993, pp. 10-13.
155. "Norway's Future in Space", Space Policy, February 1994, pp. 73-78.
156. "Norway, Sweden Shop For Rockets in Virginia", Space News, 1-7 February 1993, p. 2.
157. Advertisement in Space News, 23-29 August 1993, p. 7.

158. LM-2C Launch Vehicle, specification sheet distributed by China Great Wall Industry Corp., 1992.
159. Zhao Bing, "A System Analysis of the Launch Vehicle Technology in China", Paper 92-824, 43rd Congress of the International Astronautical Federation, August-September 1992.
160. China In Space, China Great Wall Industry Corp., 1988.
161. Space in China, Launch Services and Space Technology, China Great Wall Industry Corp., 1989.
162. Xu Jian, "Progress in Carrier Rocket Technology", Beijing Review, 3-9 September 1990, pp. 27-30.
163. G. Pike, "Chinese Launch Services, A User's Guide", Space Policy, May 1991, pp. 103-115.
164. Long March Launch System, Ministry of Astronautics, 1985.
165. P. S. Clark, "Chinese Launch Vehicles - Chang Zheng 2", Jane's Intelligence Review, May 1992, pp. 231-234.
166. P. S. Clark, "Chinese Launch Vehicles - The Rest of the Story", Jane's Intelligence Review, October 1990, pp. 469-473.
167. P. S. Clark, "Chinese Launch Vehicles - Further Details", Jane's Intelligence Review, June 1993, pp. 274-275.
168. LM-2E Launch Vehicle, specification sheet distributed by China Great Wall Industry Corp., 1992.
169. Long March-2E, specification sheet distributed by China Great Wall Industry Corp., 1991.
170. Zhongguo Xinwen She News Agency, 23 December 1992.
171. Xinhua News Agency, 21, 22, and 24 December 1992.
172. Wen Wei Po, 27 December 1992.
173. Guangming Ribao, 2 February 1993, p. 1.
174. Zhongguo Xinwen She News Agency, 23 March 1993.
175. P. Proctor, "U.S., China Examine Failed Launcher Parts", Aviation Week and Space Technology, 11 January 1993, pp. 60, 63.
176. C. Covault, "Chinese Rocket Shroud Breakup Caused Long March Failure", Aviation Week and Space Technology, 18 January 1993, p. 28.
177. "Restrictions Slow Long March Probe", Aviation Week and Space Technology, 8 February 1993, p. 25.
178. P. B. de Selding and P. Seitz, "Investigators Fail To Find Cause of Optus Loss", Space News, 8-14 February 1993, pp. 3, 20.

179. "Hughes Clears Optus Satellite in Long March Accident Probe", Aviation Week and Space Technology, 12 April 1993, p. 60.
180. LM-3 Launch Vehicle, specification sheet distributed by China Great Wall Industry Corp., 1992.
181. Long March-3, specification sheet distributed by China Great Wall Industry Corp., 1991.
182. Long March 3 User's Manual, Ministry of Astronautics, May 1985.
183. P. S. Clark, "Chinese Launch Vehicles - Chang Zheng 3", Jane's Intelligence Review, August 1992, pp. 372-376.
184. Wang Zhiren and Gu Mingchu, "Oxygen/Hydrogen Rocket Engine For CZ-3", Paper IAF-89-299, 40th Congress of the Astronautical Federation, October 1989.
185. Xinhua News Agency, 7 January 1992.
186. "Chinese Satellite Ends Up in Wrong Orbit", Spaceflight, February 1992, p. 38.
187. Xinhua News Agency, 5 May 1995.
188. Reuters, Beijing, 7 June 1995.
189. LM-4 Launch Vehicle, specification sheet distributed by China Great Wall Industry Corp., 1992.
190. Long March-4, specification sheet distributed by China Great Wall Industry Corp., 1991.
191. P. S. Clark, "Chinese Launch Vehicles - Feng Bao 1", Jane's Intelligence Review, April 1992, pp. 188-191.
192. P. S. Clark, "Chinese Launch Vehicles - Chang Zheng 1", Jane's Intelligence Review, November 1991, pp. 508-511.
193. Z. Huang, "Fully Reusable Launch Vehicle with Airbreathing Booster", Paper IAF-83-376, 34th Congress of the International Astronautical Federation, October 1983.
194. "Chinese Studying TSTO-Based Space Transportation System", Aviation Week and Space Technology, 9 December 1991, p. 70.
195. China Jinqian Satellite Launch Center, brochure, undated.
196. China Xichang Satellite Launch Center, brochure, undated.
197. Zhongguo Xinwen She News Agency, 30 September 1994.
198. V. P. Glushko, Rocket Engines GDL-OKB, Novosti Press Agency Publishing House, 1975,
199. V. P. Glushko, Razvitiye Raketostroiya i Kosmonavtika B CCCP, Mashinostroenie Press, 1981 and 1987 editions.

200. V. P. Glushko, Kosmonavtika Encyclopedia, Sovetskaya Encyclopedia, 1985.
201. P.S. Clark, USSR Rocket Engines, Second Edition, Technology Detail, undated.
202. Specifications on Application of the Vostok-Type Carrier Rocket, GLAVKOSMOS, 1987.
203. General Characteristics of Launch Vehicle Cosmos, brochure, Polet Design Bureau, undated.
204. V. Khokhlov, Interview with M.F. Reshetnev, Vozdushnyy Transport, September 1994, p. 6.
205. Advertisement, Space News, 5-11 June 1995, p. 10. (Note launch statistics include non-orbital missions).
206. A. Ryazhskih, "Space Missile Complexes", Aviation and Space News, No. 1, 1993, pp. 28-30.
207. S. Saratov, "Missile Complex Pioneer (Rocket SS-20)", Aviation and Space News, No. 1, 1993, pp. 48-49.
208. Start, the Transportable Space Launchers, brochure, undated.
209. Yu. S. Solomonov, "The 'Start' Family Launchers", Space Bulletin, Vol. 1, No. 1, 1993, pp. 20-23.
210. Krasnaya Zvezda, Moscow, 25 May 1993, p. 2; 27 March 1993; and 2 December 1992, p. 4.
211. Novosti Kosmonavтики, 15-28 March 1993, pp. 12-14; 12-25 April 1993, pp. 19-20; 24 May-6 June 1993, p. 21.
212. V. Kiernan, "Russia To Test Commercial Version of ICBM", Space News, 8-14 June 1992, pp. 1, 28.
213. The "Start" Space Launchers, brochure, Elbe Space and Technology Dresden, undated.
214. P. Seitz, "CTA Seeks SS-25 To Launch Satellites", Space News, 6-12 September 1993, p. 3.
215. Radio Australia, external service, Melbourne, 21 March 1995.
216. W. Ferster, "Australia Seeks Commercial Launch Role", Space News, 24-30 April 1995, p. 24.
217. Rocket Launch Vehicle, technical brochure distributed by Salyut Design Bureau, 1993.
218. Krasnaya Zvezda, 23 January 1992, p. 4.
219. Nezavisimaya Gazeta, 22 January 1992, p. 3.
220. Izvestiya, 21 January 1992.
221. Komsomolskaya Pravda, 3 April 1993, pp. 1, 6.
222. Rocket Launch Vehicle, technical brochure distributed by Khrunichev State Space Scientific Production Center, Moscow, 1995.
223. Novosti Kosmonavтики, 17-31 December 1994, pp. 23-24.

224. I. Matveyeva and R. Prokolov, Kommersant Daily, 3 June 1994, p. 1.
225. "Germany, Russ Might Bend Rules of Road", Military Space, 19 September 1994, p. 5.
226. "New Russian Launcher Tested", Spaceflight, May 1992, p. 146.
227. P.B. de Selding, "Rockot Launcher To Go Commercial", Space News, 20-26 February 1995, pp. 3, 6.
228. P.B. de Selding, "Rockot Venture Pursues Plan To Repay Russian Debts", Space News, 12-18 June 1995, p. 14.
229. Aviatsiya i Kosmonavtika, May 1993, pp. 42-44.
230. "Makeyev Offers Site", Aviation Week and Space Technology, 26 April 1993, p. 65.
231. S. Tutorskaya, Izvestiya, 7 August 1993.
232. G. Lomanov, "Americans To Join Missiles' Recycling Project 'Priboi'", Moscow News, 1 October 1993, p. 8.
233. S. Golotyuk, Vozdushnyy Transport, September 1993, p. 5.
234. J.M. Lenorovitz, "U.S. Entrepreneurs Seek Russian SLBMs", Aviation Week and Space Technology, 19 April 1993, p. 22-23.
235. J.M. Lenorovitz, "U.S.-Russian SLBM Venture Plans Initial Test for 1994", Aviation Week and Space Technology, 3 May 1993, p. 60-61.
236. "Surf Launcher Uses Recycled Missiles", Aviation Week and Space Technology, 21 June 1993, p. 62.
237. "Design Begins on Russian SLBM Conversion Plan", Aviation Week and Space Technology, 2 August 1993, p. 25.
238. J.M. Lenorovitz, "Russian Maker of SLBMs Seeks Civilian Spin-Offs", Aviation Week and Space Technology, 9 August 1993, pp. 48-49.
239. J.M. Lenorovitz, "Payloads Sought for Former SLBMs", Aviation Week and Space Technology, 4 January 1994, p. 54.
240. B. Iannotta, "Two U.S. Firms Set Sights on Sea-Launched Rockets", Space News, 29 November - 5 December 1993, p. 8.
241. A. Lomanov, Moskovskiye Novosti, 31 October 1993, p. B12.
242. Burlak Aviation Complex, brochure, 1991.
243. "Russians Improve Planned Payload of Air-Launched Booster", Aviation Week and Space Technology, 24 August 1992, p. 65.

244. J.M. Lenorovitz, "Germany's DARA Studies Burlak Booster", Aviation Week and Space Technology, 27 June 1994, pp. 73-75.
245. Specifications on Application of the Soyuz Carrier Rocket, GLAVKOSMOS, Moscow, 1987.
246. Novosti Kosmonavтики, 12-25 February 1994, p. 30.
247. B. Konovalov, Izvestiya, 24 March 1993, p. 5.
248. Krasnaya Zvezda, 27 March 1993.
249. Interfax News Agency, 14 October 1993 and 8 December 1994.
250. ITAR-TASS News Agency, 2 October 1994 and 12 March 1995.
251. "Rus Rocket to Replace Soyuz Booster Family", Space News, 10-16 May 1993, p. 9.
252. P.B. de Selding, "Proton, Soyuz Upgrades Lead Other Priorities", Space News, 6-12 December 1993, p. 10.
253. V.V. Vakhnichenko and M.V. Sinelshchikov, "Russian Launch Vehicles' State-of-the-Art and Lines of their Improvement", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 33-36.
254. Specifications on Application of the Molniya Carrier Rocket, GLAVKOSMOS, Moscow, 1987.
255. Fregat Upper Stage, fact sheet distributed by ARKOS Innovation Company, Khimki, 1992.
256. V.A. Asiushkin and O.V. Papkov, "Rocket Stage - Trans-Orbit Booster Fregat", Paper IAF-93-V.2.608, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
257. B. Konovalov, Izvestiya, 20 November 1993, p. 15.
258. V.A. Asiushkin, "Fregat Booster Stage and Modernization of the Launch Vehicles", 43rd Congress of the International Astronautical Federation, August-September 1992.
259. Proton Soviet Launcher, technical brochure distributed by GLAVKOSMOS, 1986.
260. Soviet Launch Vehicle "Proton" For Injecting Satellite in Geostationary Orbit, Moscow, circa. 1987.
261. Soviet Launcher Proton, Licensintorg, 1986.
262. G. Maksimov, Aviatsiya i Kosmonavtika, Moscow, August 1988, pp. 40-41.
263. S. Chenard, "Moscow's Proton Factory", Space Markets, No. 1., 1990, pp. 10-14.
264. F. A. Beswick, "Proton Launcher at Baikonur", Spaceflight, September 1992, pp. 298-301.



265. D. Poluhin, "Russian 'Proton' Launch Vehicle, Its History, Design and Uses", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 37-41.
266. V. Petrakov and I. Afanashev, Aviatsiya i Kosmonavtika, April 1993, pp. 10-12.
267. Novosti Kosmonavtiki, 12-25 February 1994, pp. 27-29.
268. Proton, technical brochure distributed by the Salyut Design Bureau, undated.
269. Proton, technical brochure distributed by Lockheed-Khrunichev-Energia, undated.
270. Proton Launcher, User's Guide, Salyut Design Bureau, 1992.
271. A.I. Kiselev, et al, "The Launch Vehicle 'Proton': The History of its Creation, Peculiarities of its Structure and Prospects for Development", Space Bulletin, Vol. 1, No. 4, 1994, pp. 5-7.
272. Novosti Kosmonavtiki, 9-22 October 1993, pp. 26-27.
273. B. Iannotta, "Proton Misplaces Russian Gorizont", Space News, 31 May - 6 June 1993, pp. 1, 21.
274. P.B. de Selding, "Russian Commission Investigates Proton Mishap", Space News, 7-13 June 1993, pp. 3, 29.
275. "Falling Proton Booster Tested New Abort Mode", Aviation Week and Space Technology, 28 June 1993, p. 26.
276. P.B. de Selding, "Bad Fuel Mix Cited in Proton Failure", Space News, 13-19 September 1993, pp. 1, 20.
277. Fact Sheet, U.S. - Russian Commercial Space Launch Agreement, The White House, Office of the Vice President, 2 September 1993.
278. The Federal Register, Guidelines for U.S. Implementation of the Agreement Between the U.S. and Russian Federation Government Regarding International Trade in Commercial Space Launch Services, 10 March 1994, pp. 11360-11363.
279. T. Furniss, "The Proton Threat", Space, March-April 1995, pp. 10-12.
280. W. Ferster, "Russia: Relax Launch Limits", Space News, 19-25 December 1994, pp. 1, 21.
281. P.B. de Selding, "Despite Global Appeal, Russia's Proton Faces Obstacles", Space News, 10-16 October 1994, p. 9.
282. P.B. de Selding, "Russian Lawmakers Stall Satellite Accord", Space News, 11-17 April 1994, pp. 1, 28.
283. A. Lawler, "Russia Protests Launch Guidelines", Space News, 11-17 April 1994, pp. 3, 29.
284. Novosti Kosmonavtiki, 9-22 October 1993, pp. 31-32.
285. V. Naumov, Rossiyskiye Vesti, 15 June 1993.

286. P.B. de Selding, "NPO Energia Joins Lockheed, Khrunichev To Market Protons", Space News, 19-25 April 1993, pp. 1, 28.
287. Technical materials distributed by Energiya NPO, Moscow, 1991.
288. "Soviets Developing Smaller Version of Energia Heavy-Lift Booster", Aviation Week and Space Technology, 24 December 1990, p. 79.
289. "Energia M Launcher, Designed to Carry Smaller Payloads Than Standard Version", Aviation Week and Space Technology, 10 June 1991, p. 48.
290. Yu. Semenov, presentation to the 42nd Congress of the International Astronautical Federation, October 1991.
291. A.N. Shorin and V.V. Liberman, "Energia-M: One of the Family of Modern Launchers", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 71-76.
292. V. Filin, "The Energiya-M Booster Rocket: Prospects of Using It For Dumping of Radioactive Waste in Outer Space", Aviation and Space News, No. 1, pp. 31-34.
293. Energia-M, technical brochure distributed by Energiya Scientific Production Association, undated.
294. "Russia Abandons Plans for Energia-M Launcher", Space News, 29 November - 5 December 1993, p. 2.
295. Angara Launch Vehicle, technical brochure distributed by Khrunichev State Space Research and Production Center, 1995.
296. ITAR-TASS News Agency, Moscow, 16 March 1994.
297. Moskovskaya Pravda, 31 March 1994, p. 5.
298. Interfax News Agency, Moscow, 18 August, 29 August, and 13 October 1994.
299. Nezavisimaya Gazeta, 20 August 1994, p. 2.
300. A. Malyutin, Kommersant Daily, 2 September 1994, p. 9.
301. "Russians Consider Winged Booster", Aviation Week and Space Technology, 6 September 1993, p. 60.
302. G. Lozino-Lozinsky, "'Buran,' Its Creation and Prospects of Its Usage", 40th Congress of the International Astronautical Federation, October 1989. See also V. V. Ryumin, "The 'Buran' Orbiter Flight Control and Preparation" at the same conference.
303. "Improvements to Third Soviet Shuttle", Spaceflight, May 1990, p. 147.
304. J. M. Lenorovitz, "Soviets' Second Buran Orbiter Undergoes Launch Pad Tests", Aviation Week and Space Technology, 12 August 1991, pp. 38-40.

305. "Assembly of Second Orbiter Completed at Cosmodrome", Aviation Week and Space Technology, 10 June 1991, p. 49.
306. S.V. Chekalin, "Reusable Launchers Being Designed in Russia", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 139-142.
307. M. Rudenko, Vozdushnyy Transport, June 1994, pp. 8-9.
308. Khimiya i Zhizn, October 1993, pp. 40-44.
309. Radio-1, Moscow, 30 June 1993.
310. Russia's Radio, Moscow, 16 November 1993.
311. G. E. Lozino-Lozinsky et al, "Reusable Aerospace System with Horizontal Take-Off", Paper IAF-90-176, 41st Congress of the International Astronautical Federation, October 1990.
312. G. E. Lozino-Lozinsky et al, "Multi-Purposed Aerospace System MAKS and Its Outlook", Paper IAF-92-851, 43rd Congress of the International Astronautical Federation, August-September 1992.
313. M. Hempzell and B. Parkinson, "MAKS - Eastern Promise?", Spaceflight, March 1993, pp. 79-83.
314. D. Hughes, "Russian Liquid Rocket Bureau Designing Three-Fuel Engine", Aviation Week and Space Technology, 30 March 1992, p. 23.
315. "From 'Spiral' to MAKS", Man and Space, No. 1, 1992, pp. 26-28.
316. G. Laruelle, et al, "Europeans Pursue Air-breathing Propulsion", Aerospace America, February 1994, pp. 22-25.
317. L. van den Abeelen, "MAKS: An Update", Spaceflight, January 1994, pp. 24-25.
318. Zemlya i Vselennaya, May-June 1991, pp. 19-26.
319. V.G. Aliev, et al, "The Main Concepts and Streams of Evolution of Space Transportation Systems for the Mir-Type Long-Term Orbital Complexes Servicing", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 163-170.
320. Rossiia, 24 February - 1 March 1993, p. 11.
321. Kommersant Daily, 23 October 1993, p. 8.
322. Segodnya, 7 October 1993, p. 8.
323. Nezavisimaya Gazeta, 14 December 1993, p. 6.
324. Finansovyye Izvestiya, 18-24 August 1994, p. 4.

325. Nezavisimaya Gazeta, 12 April 1994, p. 6.
326. Aviatsiya I Kosmonavtika, September-October 1993, pp. 12-15.
327. Segodnya, 6 October 1994, p. 9.
328. Krasnaya Zvezda, 23 June 1994, p. 4.
329. A.S. Roudakov, et al, "Flight Testing on Axisymmetric Scramjet - Russian Recent Advances", Paper IAF-93-S.4.485, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
330. V.L. Semenov and A.I. Lanshin, Aviatsiya I Kosmonovtika, January - February 1994, pp. 36-38.
331. S. Leskov, Izvestiya, 12 February 1992, p. 2.
332. S. Leskov, Poisk, 2-8 May 1992, p. 13.
333. P.B. de Selding, "Russia Claims First Scramjet Flight", Space News, 3-9 February 1992, p. 3.
334. "Russian Ramjet/Scramjet Operates Successfully", Aviation Week and Space Technology, 31 August 1992, p. 24.
335. S.W. Kandebo, "Russians Want U.S. to Join Scramjet Tests", Aviation Week and Space Technology, 30 March 1992, pp. 18-20.
336. S.W. Kandebo, "Franco-Russian Tests May Spur New Projects", Aviation Week and Space Technology, 14/21 December 1992, pp. 70-72.
337. P.B. de Selding, "Russians Seek French Francs for Engine Test", Space News, 18-24 October 1993, p. 4.
338. P.B. de Selding, "French to Support Third Test of Russian Scramjet Engine", Space News, 25 April - 1 May 1994, p. 8.
339. L. M. Shkadov, et al, "Comparative Analysis of Various Concepts For Reusable Aerospace Systems", Paper IAF-92-865, 43rd Congress of the International Astronautical Federation, August-September 1992.
340. W. Ferster, "Russian Rocket Engines Vie for Role in EELV Effort", Space News, 8-14 May 1995, p. 12.
341. P. Seitz, "Russian Rocket Engines Stalled in West", Space News, 10-16 April 1995, p. 6.
342. B. Iannotta, "Russian Power for X-34?", Space News, 26 June - 2 July 1995, pp. 1, 28.
343. Interfax News Agency, 5 April 1995.
344. J.M. Lenorovitz, "Tripropellant Engine Tested for SSTO Role", Aviation Week and Space Technology, 11 July 1994, p. 4.
345. B. Iannotta, "Engineers Study Russian Tripropellant Technology", Space News, 7-13 November 1994, p. 6.

346. RD-701, technical brochure distributed by Pratt and Whitney and Energomash NPO, 1993.
347. RD-120, technical brochure distributed by Pratt and Whitney and Energomash NPO, 1993.
348. J.M. Lenorovitz, "Energomash Develops New RD-170 Versions", Aviation Week and Space Technology, 2 August 1993, p. 64.
349. J.T. McKenna, "Atlas Managers Await RD-180 Model", Aviation Week and Space Technology, 12 September 1994, pp. 55-57.
350. "Pratt, Energomash Explore RD-170 Engine Applications", Aviation Week and Space Technology, 26 July 1993.
351. V. Kiernan, "Russian Engine Marketers Fume at Slow U.S. Response", Space News, 11-17 May 1992, p. 23.
352. A. Lawler, "Energomash Seeks RD-180 Sales in West", Space News, 19-25 April 1993, p. 12.
353. Rossiyskiye Vesti, 20 February 1993, p. 6.
354. W.B. Scott, "Aerojet to Receive Russian NK-33s", Aviation Week and Space Technology, 24 April 1995, p. 46.
355. "Aerojet, Lyulka Push D-57 for SSTD Validation", Aviation Week and Space Technology, 11 October 1993, pp. 50-51.
356. P. Langereux, "Francais et Americains Se Disputent Les Meilleurs Moteurs-Fusees Russes", Air & Cosmos, 31 October 1993, pp. 40-41.
357. Liquid-Propellant Rocket Engine D-57, technical brochure distributed by Lyulka Engine Design Bureau, undated.
358. RD-120K and RD-161, technical brochures distributed by Energomash NPO, undated.
359. M.A. Dornheim, "Aerojet Imports Trud NK-33 Rocket Engine", Aviation Week and Space Technology, 25 October 1993, p. 29.
360. J.M. Lenorovitz, "Aerojet Seeks OK to Test NK-33 Engine", Aviation Week and Space Technology, 24 October 1994, p. 25.
361. Multiple-Shot Liquid-Propellant Rocket Engine for First Stage of Launch Vehicles (NK-33), technical brochure distributed by Trud NPO, undated.
362. S. P. Aksjonov, et al, "Experience of the Chemical Automatics Design Bureau in Creation of RD-0120 LOX/H<sub>2</sub> Liquid Rocket Engine with Thrust of 2 MN for 'Energiya' Launcher", Symposium on Launcher Propulsion Towards the Year 2010, June 1991.
363. J.M. Lenorovitz, "Trud Offering Liquid-Fueled Engines From N1 Moon Rocket Program", Aviation Week and Space Technology, 30 March 1992, pp. 21-22.

364. T. Foley, "Bush, Clinton Blink at Secret Purchase of Zenit Engines", Space News, 1-7 November 1993, pp. 1, 20.
365. Stationary Plasma Thruster (SPT-100), technical brochure distributed by ISTI, undated.
366. S.D. Grishin and L.V. Leskov, Electrical Engines for Space Vehicles, Mashinostroyeniye Press, 1989.
367. E.J. Lerner, "Plasma Thrusters from Russia", Aerospace America, September 1992, p. 51.
368. "Russian Thruster Cleared for Western Use", Military Space, 28 November 1994, pp. 5-6.
369. B.A. Arkhipov, et al, "Development and Investigation of Characteristics of SPT Models with Increased Power", Paper IAF-93-S.5.488, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
370. A.I. Rudikov, "Pulsed Plasma Thruster of Erosion Type for a Geostationary Artificial Earth Satellite", Paper IAF-93-S.5.487, 44th Congress at the International Astronautical Federation, 16-22 October 1993.
371. Kommersant Daily, 20 February 1993, p. 4.
372. "SEP Thruster Alliance", Aviation Week and Space Technology, 28 June 1993, p. 24.
373. Moskovskaya Pravda, 11 February 1994, p. 15.
374. "Electric Propulsion", Aerospace America, December 1993, p. 52.
375. "Palo Alto Company Tests Russian Thruster System", Space News, 25-31 October 1993, p. 12.
376. Transactions of the Anniversary Specialist Conference on Nuclear Power Engineering in Space, Parts I and II, Obninsk, 15-19 May 1990.
377. See the papers of the annual Symposium on Space Nuclear Power Systems, Institute for Space Nuclear Power Studies, Albuquerque, since 1989. In particular, see  
V.I. Brukhty, et al, "Electric Propulsion for Space Research", 1990;  
V.A. Pavshoock, et al, "Criterion for the Selection of Power Propulsion Complex for Manned Interplanetary Missions", 1990; and  
M.S. Belyakov, et al, "The Problems of the Brayton Cycle Application in a Biomodal Nuclear Power Propulsion System", 1990.
378. V. Kiernan, "Russians: Site Tested Rockets, Not Beam Weapon", Space News, 12-18 October 1992, p. 1.
379. L. David, " Soviets Reveal Work In Advanced Nuclear Rockets, Seek to Share", Space News, 16-22 September 1991, p. 18.
380. Panorama, 13 May 1995, p. 3.
381. T. Foley, "Space Nuclear Power Faces Bleak Future", Space News, 16-22 January 1995, p. 6.

382. J.S. Clark, et al, "U.S./CIS Eye Joint Nuclear Rocket Venture", Aerospace America, July 1993, pp. 28-30, 35.
383. "Russians to Offer Their Nuclear Thermal Propulsion Technology to U.S.", Aviation Week and Space Technology, 20 January 1992, p. 21.
384. O. Borisov, Pravda Vostoka, 7 August 1991, p. 3.
385. N. Krivomazov, Pravda, 11 February 1992, p. 1.
386. A. Polyarnyy, Krasnaya Zvezda, 5 March 1989, p. 4.
387. P. Novikov, Rabochaya Tribuna, 28 December 1991, p. 4.
388. The US-Russian Topaz II electric power system program has undergone significant redirections in recent years and original plans to orbit Topaz II reactors have been deferred indefinitely. For some recent summaries of the program see:  
L. David, "U.S. Poised to Build on Russia's Topaz Technology", Space News, 17-23 April 1995, p. 8;  
L. David, "Amid Some Skepticism, America Begins Testing Russian Space Reactor", Space News, 14-20 November 1994, p. 18;  
S. Morgachev, Kommersant Daily, 29 January 1994, p. 8;  
T. Foley, "U.S. Nuclear Space Projects Ebb Again", Space News, 10-16 January 1994, pp. 1, 10;  
B. Iannotta, "Nuclear Policy Firm Despite Topaz Purchases", Space News, 16-22 May 1994, p. 10;  
B. Iannotta, "Air Force Hunts Cash to Buy Topaz Reactors", Space News, 28 February - 6 March 1994, p. 10;  
B. Iannotta, "Budget Woes Force BMDO to Recoil on Topaz Buy", Space News, 15-28 November 1993, pp. 4, 29.
389. Oversight Visit, Baikonur Cosmodrome, House Report 103-451, House of Representatives, US Congress, 23 March 1994.
390. V. Kravtsov, Pravda, 4 January 1993, p. 4.
391. A. Zak, Nezavisimaya Gazeta, 9 February 1993, p. 6.
392. M. Rebrov, Delovoy Mir, 30 July 1993, p. 15.
393. A. Zak, Nezavisimaya Gazeta, 13 July 1993, p. 6.
394. V. Chernobrov, Rossiyskiye Vesti, 7 July 1993, p. 7.
395. O. Volkov, Novaya Yezhednevnyaya Gazeta, 14 July 1993, p. 2.
396. A. Shumilin, Pravda, 7 September 1993, pp. 1-2.
397. O. Moroz, Literaturnaya Gazeta, 10 November 1993, p. 9.
398. V. Ardayev, Izvestiya, 28 December 1993, p. 2.

399. Novosti Kosmonavtiki, 20 November - 3 December 1993, pp. 26-29 and 18-31 December 1993, pp. 31-34.
400. V. Ardayev, Izvestiya, 14 January 1994, p. 2.
401. I. Marinin, Novosti Kosmonavtiki, 17-25 February 1994, pp. 37-41 and 26 February - 11 March 1994, p. 37.
402. L. Minasyan, Nezavisimaya Gazeta, 12 February 1994, p. 3.
403. V. Kononenko, Izvestiya, 30 March 1994, p. 3.
404. O. Falichev, Krasnaya Zvezda, 30 March 1994, p. 1.
405. S. Tsekhmistrenko, Kommersant Daily, 2 April 1994, p. 4.
406. T. Sarabekova, Panorama, 25 June 1994, p. 3.
407. Yu. Konorov, Rossiyskiye Vesti, 19 July 1994, p. 5.
408. V. Li, Kazakstanskaya Pravda, 5 July 1994, p. 1.
409. V. Bezborodov, Krasnaya Zvezda, 22 October 1994, p. 4.
410. S. Leskov, Izvestiya, 28 December 1994, p. 2.
411. J. Villain, "Baikonour Grandeur et Decadence", Science et Vie, November 1994, pp. 106-109.
412. J.M. Lenorovitz, "Russia Signs Pact on Asian Launch Site", Aviation Week and Space Technology, 19 September 1994, p. 25.
413. P.B. de Selding, "Cosmodrome's Operators Cite Deteriorating Conditions", Space News, 10-16 October 1994, p. 7.
414. Baikonur, La Porte Des Etoiles, SEP, Armand Colin, Paris, 1994.
415. B. Morozov, "Plesetsk", Aviatsiya I Kosmonavtika, June 1993, pp. 40-41.
416. G. Mashtakova, Rossiia, 14-20 July 1993, p. 9.
417. V. Romanenkova and S. Ivanov, Segodnya, 17 March 1994, p. 9.
418. Rossiyskaya Gazeta, 6 March 1994, p. 4.
419. M. Kirtser, Kommersant Daily, 16 April 1994, p. 22.
420. K. Lantratov, Novosti Kosmonavtiki, 12-25 February 1994, pp. 41-45.
421. A Stepovoy and V. Filippov, Izvestiya, 6 October 1994, p. 4.



422. K. Lantratov, Novosti Kosmonavтики, 3-16 December 1994, pp. 30-31.
423. V. Kiernan, "Russia Plans New Cosmodrome Outside Kazakhstan", Space News, 21-27 March 1994, p. 8.
424. S. Ivanov and V. Romanenkova, Rossiyskaya Gazeta, 12 March 1994, p. 1.
425. N. Belyi, Rossiyskiye Vesti, 17 March 1994, p. 12.
426. V. Karkavtsev, Komsomolskaya Pravda, 26 March 1994, p. 3.
427. V. Romanenko and S. Ivanov, Segodnya, 24 March 1994, p. 9.
428. B. Ostroumov and I. Barmin, Rossiyskaya Gazeta, 2 April 1994, p. 3.
429. O. Kryuchek, Segodnya, 3 December 1994, p. 2.
430. N. Savin, Komsomolskaya Pravda, 27 December 1994, p. 3.
431. M. Sergeyev, Kommersant Daily, 16 January 1993, p. 2.
432. V. Karkavtsev, Komsomolskaya Pravda, 3 April 1993, p. 6.
433. V. Tyagniryadno, Segodnya, 20 October 1994, p. 9.
434. Rossiyskaya Gazeta, 11 May 1994, p. 4.
435. P. B. de Selding, "Spain Boosts Space Spending, Plans New Launch Vehicle", Space News, 15-21 June 1992, p. 6.
436. "Spanish Orbital Rocket", Spaceflight, August 1992, p. 249.
437. "Spanish Satellite Project Matures", Aviation Week and Space Technology, 21 June 1993, p. 26.
438. "Spain Tables Launcher Program, Eyes Pegasus", Space News, 11-17 April 1994, p. 2.
439. P.B. de Selding, "Swedes Tap Start-1, Switch to Plesetsk", Space News, 30 May - 12 June 1994, pp. 1, 21.
440. Specifications on Application of the Tsyklon Carrier Rocket, GLAVKOSMOS, 1987.
441. S. Sergeyev, Aviatsiya i Kosmosnavtika, March-April 1994, pp. 38-41.
442. K. Lantratov, Novosti Kosmonavтики, 15-28 January 1994, pp. 31-34.
443. Cyclone, technical brochure distributed by Yuzhnoye Design Bureau, undated.
444. Novosti Kosmonavтики, 22 October - 4 November 1994, pp. 52-53.
445. The Multi-Purpose Space Rocket Complex "Zenit", GLAVKOSMOS, 1989.

446. Y. A. Smetanin, "Rocket Space Transportation Systems Produced by 'Yuzhnoye' Rocket-Space Association", Paper IAF-92-862, 43rd Congress of the International Astronautical Federation, 1992.
447. Y. A. Smetanin, "GLAVKOSMOS Operational Space Transportation Systems", GLAVKOSMOS, 1989.
448. Zenit, brochure distributed by Cape York Space Agency and GLAVKOSMOS, 1990.
449. Y. Smetanin and V. Obukhovskiy, "Salient Features of the 'Zenit' Space-Transportation System", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 57-66.
450. S. Konyukhov, "Space Research by the Zenit Rocket-Space Complex", Paper IAF-93-V.4.623, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
451. Zenit, technical brochure distributed by Yuzhnoye Design Bureau, undated.
452. C. Lardier, "Nouvelles Utilisations De La Fusee Zenith", Air & Cosmos, 4 November 1994, p. 39.
453. Novosti Kosmonavтики, 12-25 February 1994, pp. 30-31.
454. V. Menshikov, Aviatsiya I Kosmonavtika, November-December 1993, pp. 42-43.
455. J. Rossie and J. Forrest, "Zenit at Baikonur", Spaceflight, October 1994, pp. 326-327.
456. G. Chernyavskiy, et al, "The Recent Fragmentations of LEO Upper Stages", Paper IAA-94-IAA.6.5.696, 45th Congress of the International Astronautical Federation, 9-14 October 1994.
457. Interfax News Agency, Moscow, 21 June 1993.
458. L. David, "Now Private Firm Plans to Sell Energia, Zenit to West", Space News, 24-30 May 1993, p. 19.
459. A. Lawler, "East-West Launch Vehicle Venture in Turmoil", Space News, 8-14 August 1994, p. 5.
460. W.A. Good, AIAA Rocky Mountain Section Newsletter, December 1994, p. 7.
461. A. Lawler, "Russian, Ukrainian, U.S. Giants Plan Zenit Venture", Space News, 20-26 June 1994, pp. 1, 20.
462. "International Team Offers Sea Launches", Aviation Week and Space Technology, 17 April 1995, p. 25.
463. Economic News Agency, Moscow, 6 April 1995.
464. S. Ilchenko, Rabochaya Tribuna, 2 June 1992, p. 2.
465. "Ukrainians Plan To Add Muscle to Zenit Rocket", Space News, 14-20 June 1993, p. 2.
466. W. Ferster and P.B. de Selding, "Zenit, Cyclone Parley To Start", Space News, 10-16 April 1995, p. 1.
467. P.B. de Selding, "RKA Chief Blasts Loral's Zenit Deal", Space News, 19-25 June 1995, p. 1.

468. W. Ferster, "U.S. Eyes Zenit Warily", Space News, 12-18 December 1994, pp. 1, 28.
469. UNIAN, Kiev, 17 October 1994.
470. P.B. de Selding, "Russia Ready To Use Ukraine-Built Zenits", Space News, 3-9 October 1994, pp. 1, 21.
471. C. Covault, "Ukraine Accelerates Space Projects", Aviation Week and Space Technology, 27 June 1994, pp. 72-73.
472. C. Lardier, "The Formidable SS-18s Being Scrapped", Air & Cosmos, 2 September 1994.
473. Y. Smetanin and O. Drobakhin, "SS-18K Launcher Derived from Combat Missile (Main Characteristics)", Proceedings of the European Forum on Space Transportation Systems, ESA SP-362, March 1994, pp. 67-69.
474. Y.A. Smetanin, "Rocket Space Transportation Systems, Produced by 'Yuzhnoye' Rocket-Space Association", Paper IAF-92-0862, 43rd Congress of the International Astronautical Federation, 28 August - 2 September 1992.
475. Technical brochure distributed by Yuzhnoye NPO, circa 1992.
476. L. David, "SS-18 Missiles Eyed For Mars Exploration Missions", Space News, 12-18 June 1995, p. 26.
477. A. Podnek, Delovoy Mir, 9 May 1992, p. 5.
478. Space Clipper Commercial Space Launch System, technical brochure distributed by Yuzhnoye NPO, undated.
479. "Soviets Eye Air-Launched ICBM To Put Civil Satellites in Orbit", Aviation Week and Space Technology, 14 October 1991, pp. 72-73.
480. P.B. de Selding, "Soviets Seek Partner For Launch Business With Refitted SS-24s", Space News, 23-29 September 1991, p. 4.
481. P. Langereux, "Une Famille De Petits Lanceurs Pour L'Europe, Le 'Talisman' De Dassault - Yuzhnoye (Ukraine)", Air & Cosmos, 17 April 1994, pp. 44-46.
482. ITAR-TASS News Agency, Moscow, 10 November 1994.
483. INFOBANK, Lvov, 11 May 1995.
484. POST-POSTUP, Lvov, 12-18 May 1995, p. 3.
485. HOTOL, brochure published by British Aerospace and Rolls Royce, undated.
486. M. Hemsell, "HOTOL's Secret Engines Revealed", Spaceflight, May 1993, pp. 168-172.
487. "New Hopes for UK Spaceplane Studies", Spaceflight, June 1993, p. 193.

- 488. C. A. Shifrin, "British Aerospace, Soviets to Study Launching HOTOL from AN-225", Aviation Week and Space Technology, 10 September 1992, p. 23.
- 489. S. Young, "Soviet Cooperation Gives Hotol a New Lease of Life", Spaceflight, October 1990, pp. 326-327.
- 490. P. B. de Selding, "Antonov-Hotol Project Passes Test", Space News, 6-12 May 1991, p. 26.
- 491. "Antonov Launched Hotol Moves Forward", Spaceflight, August 1991, p. 259.
- 492. Izvestiya, 21 June 1991, p. 8.
- 493. J. M. Lenorovitz, "New Hotol Version Emerges Following British/Soviet Study", Aviation Week and Space Technology, 9 September 1991, pp. 68-69.
- 494. S. W. Kandebo, "Soviets to Conduct Wind Tunnel Separation Tests on Hotol Launch System", Aviation Week and Space Technology, 6 January 1992, p. 58.
- 495. R. Parkinson, "Project 'Interim Hotol' Update", Space Technology International, 1992, pp. 127-128.
- 496. R. Varvill and A. Bond, "Skylon: A Key Element of a Future Space Transportation System", Spaceflight, May 1993, pp. 162-166.
- 497. "Correspondence", Spaceflight, July 1993, pp. 240-242.
- 498. "Correspondence", Spaceflight, November 1993, p. 388.

### 3.0 MANNED AND MAN-RELATED SPACE PROGRAMS

Since Yuri Gagarin first paved the way for manned space flight, 113 citizens of 27 nations in Europe and Asia have ventured into the hostile near-Earth environment (Appendix 3). However, 34 years after that historic mission only the US and the Russian Federation had developed the technological base and spacecraft necessary to carry man into space and to return him home safely to Earth. Although ESA, Japan, and the PRC have seriously considered building manned spacecraft, all three programs are on indefinite suspension with no flights possible until after the year 2000. Hence, for the remainder of this decade European and Asian astronauts must continue their reliance on American and Russian spaceships.

Despite this lack of national space transportation capability, formal man-in-space programs are developing rapidly in the Eastern Hemisphere. ESA and Japan are major partners in the International Space Station program, contributing habitable modules to the large complex, and have consequently established official astronaut training programs. In addition to its activities with ESA, France has undertaken a long-term bi-lateral agreement with USSR/Russian Federation to gain manned space flight experiences. PRC's on-again/off-again manned space program appears dormant at the present, but the country remains capable of conducting an indigenous man-in-space project or entering international endeavors.

Two of the five manned missions to Mir carried crewmen from outside the former Soviet bloc under special programs sponsored by France and ESA. Two other ESA astronauts flew on separate US Space Shuttle missions, and for the first time a Russian cosmonaut was launched on board an American spaceship. Several more international missions are scheduled before construction of the International Space Station begins in late 1997.

#### 3.1 INTERNATIONAL SPACE STATION

Ten years after President Reagan initiated the permanent space station program in 1984, the effort had finally achieved a measure of both political and technical stability. Reborn during 1993-1994 as the International Space Station Alpha (usually referred to simply as the International Space Station by late 1994), the historic endeavor now includes Canada, ESA,

Japan, the Russian Federation, and the US as the principal partners. Due to the considerable resources being applied to the International Space Station program by Europe and Asia, this subsection is designed to provide a background of the undertaking with emphasis on the general Eurasian commitments. Additional details are found in the national subsections which follow.

The earlier Space Station Freedom program was subjected to an intensive review during March-June, 1993, which led to the submission of three redesign options to US President Clinton. The tentative selection of Option A (which led to the "Alpha" moniker) had hardly been made when a special summer study, based on bilateral discussions begun in the Spring, investigated the feasibility of accepting the Russian Federation as a new principal partner. By the Fall of 1993, the Alpha design was expanded to include numerous Russian elements, and by December the Russian Federation was officially invited to join the program (References 1-15). Kazakhstan and Ukraine will be vital participants by way of the use of the Baikonur Cosmodrome and the Zenit launch vehicle, respectively, but they are independent players in the International Space Station program.

The design and schedule for the orbital facility solidified in 1994 under a three phase program. Phase 1 (aka Shuttle-Mir) constitutes increased cooperation between the US and Russian manned space programs and a series of joint flights, including seven missions in which the US Space Shuttle will dock with the Mir space station during the period 1995-1997. The veteran Russian cosmonaut Sergei Krikalev kicked-off the flight portion of this agreement as a member of the STS-60 crew in February, 1994.

Phase 2 begins in late 1997 with the launch of the US-financed, Russian-built first element of the International Space Station, the FGB module. Sixteen months later, after 14 main missions (through flight 7A) and several Russian logistical flights, Phase 2 will be completed. Figure 3.1 depicts the International Space Station after the second mission of Phase 3 (Flight 7R) scheduled for May, 1999. Assembly complete and the conclusion of Phase 3 should occur in June, 2002, after 44 main missions and a projected 29 logistical

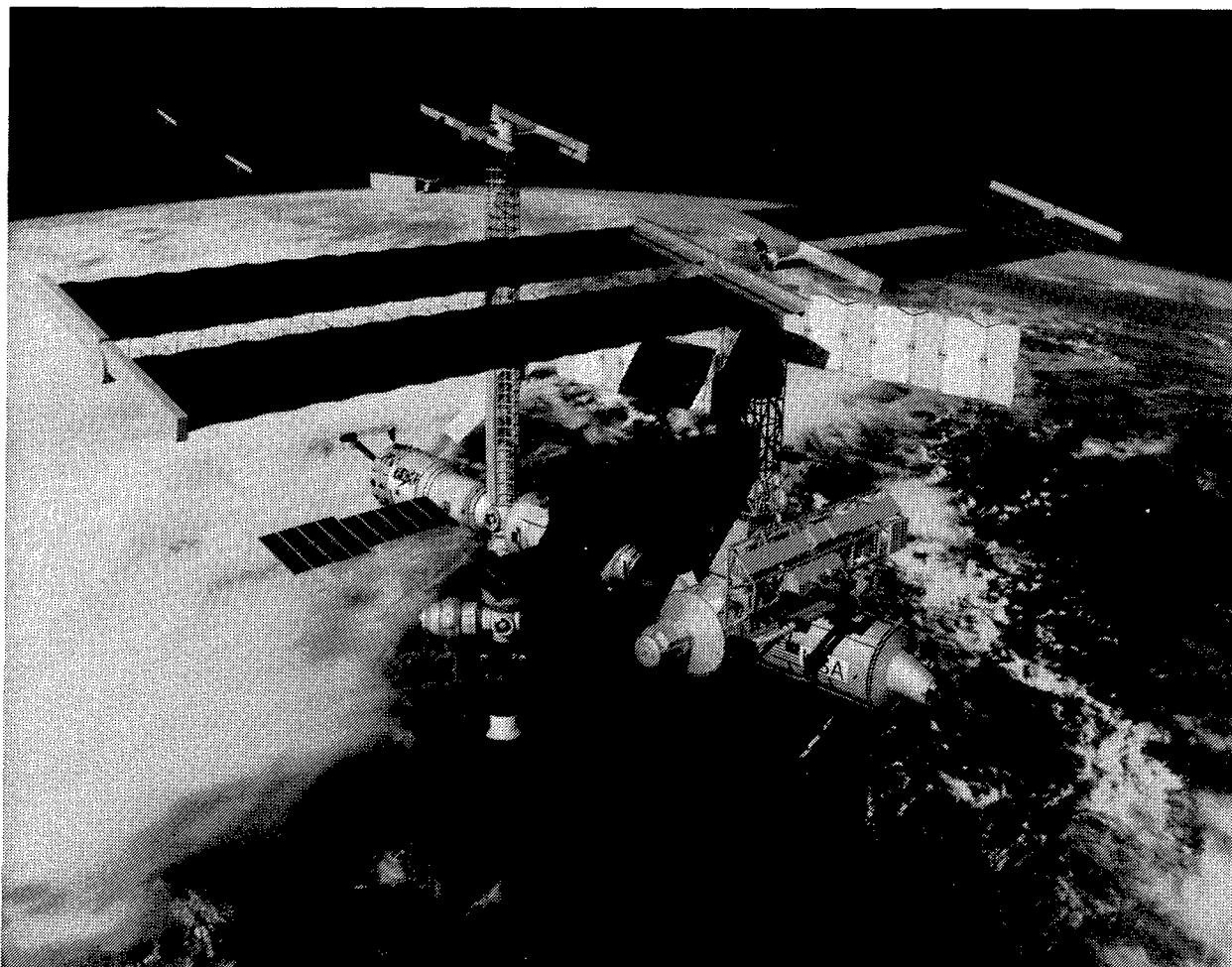


FIGURE 3.1 INTERNATIONAL SPACE STATION IN EARLY PHASE 3.

flights, primarily Russian Soyuz TM, Progress M, and Progress M2 spacecraft.

When full operational capability is achieved in 2002, the space station will consist of 17 modules with a total mass of about 420 metric tons and a pressurized volume of more than 1,300 m<sup>3</sup> (Figure 3.2). The overall length will be 110 m with a breadth of nearly 90 m. Approximately 50 kW will be generated by the combined US and Russian solar arrays. The typical crew size (between visits by the STS or Soyuz TM replenishments) will be six. The station's orbit will be on average 400 km high at an inclination of 51.6°. Table 3.1 and Figure 3.3 describe more fully the European and Asian contributions to the International Space Station as of the end of 1994 (References 16-17).

### 3.2 EUROPEAN SPACE AGENCY

The stage was set for ESA's entry into manned spaceflight in December, 1972, with a

European commitment to involve ESRO in the US Space Shuttle program and in 1973 with the signing of an agreement with the US to develop the Spacelab scientific facility for the US Space Transportation System. During 1993-1994 two European astronauts representing ESA flew on board US Space Shuttles: one in conjunction with a Spacelab mission and one to service the Hubble Space Telescope. ESA's participation in the International Space Station program will ensure an expanding role for ESA in manned space flight activities, despite the cancellations in the Columbus free-flyer and the Hermes spaceplane projects. In addition, ESA is expected to begin the development of a Crew Transport Vehicle (CTV) and an Automated Transfer Vehicle (ATV) for use in conjunction with the International Space Station.

Spacelab, which had flown on 10 STS missions between 1983 and 1992, completed five more successful flights during 1993-1994:

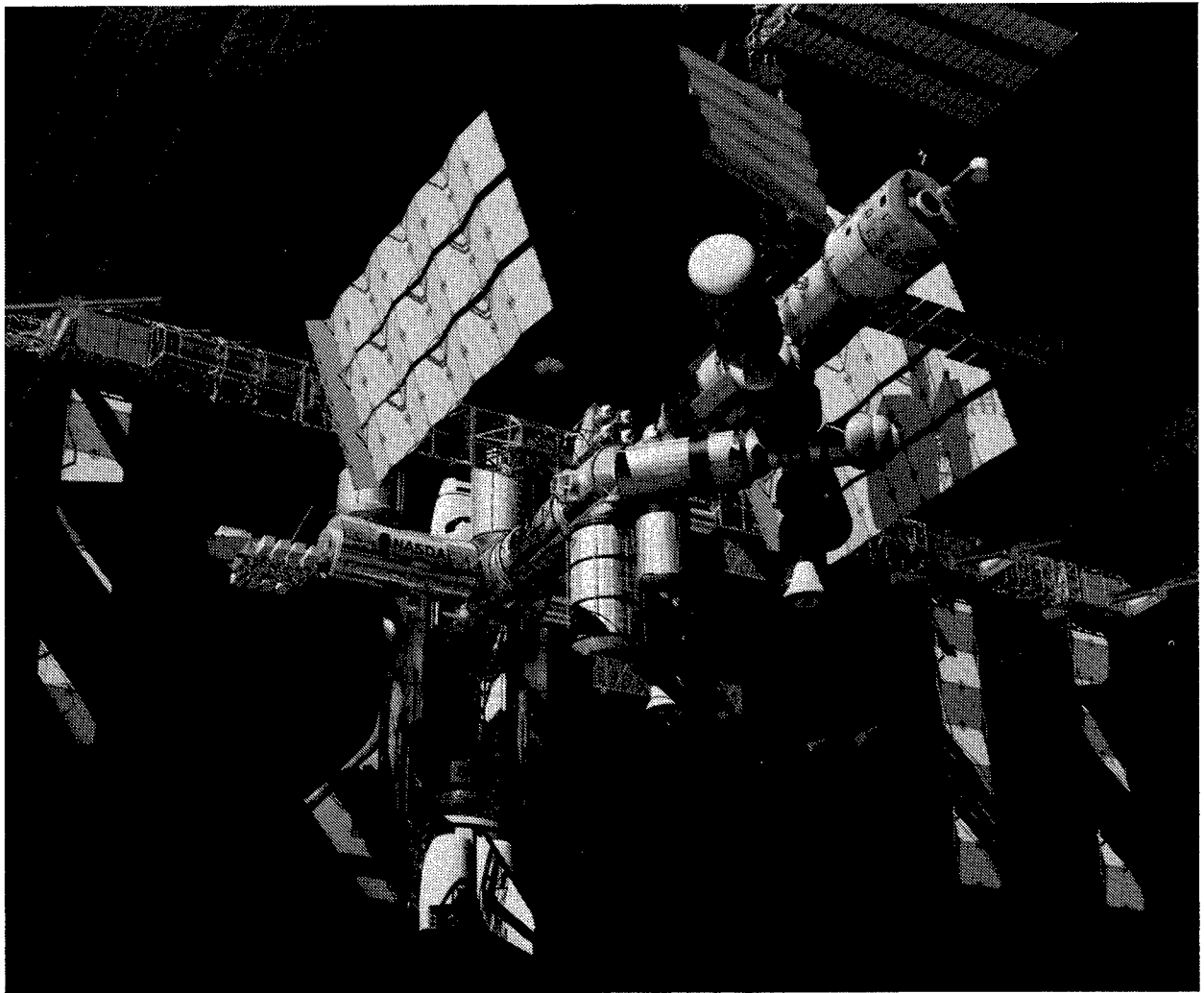


FIGURE 3.2 INTERNATIONAL SPACE STATION AT ASSEMBLY COMPLETE, YEAR 2002.

two ATLAS (Atmospheric Lab for Applications and Science), one IML (International Microgravity Laboratory), one SLS (Spacelab Life Sciences) and Spacelab-D2 for Germany. Spacelab is actually a modular system which is custom configured and outfitted for each specialized mission (Figure 3.4). The principal components employed to date are the Long Module habitable pressurized compartment (approximately 8 metric tons, 4 m diameter, and 7 m length), the exposed equipment Pallet (725 kg base mass, 4 m diameter, and 3 m length), and the pressurized equipment Igloo (640 kg base mass, 1.1 m diameter, and 2.4 m height). On manned Spacelab missions the Long Module can be flown with up to two Pallets (only non-Pallet and 1-Pallet missions have been conducted), and on unmanned flights the Long Module is replaced by an Igloo and as many as

five Pallets (only 2- and 3- Pallet missions have been conducted). A short Module configuration (length approximately 4.3 m) was part of the original Spacelab design but has not been implemented (Reference 18).

Four ESA astronauts had flown a total of seven orbital missions by the end of 1994. ESA's first astronaut and a veteran of two STS missions, Ulf Merbold, made his third flight under the Euromir 94 mission in 1994 on the Russian Soyuz-TM 20 spacecraft, including a month-long stay on the Mir space station (Section 3.8). Wubbo Ockels flew on a STS mission in 1985 and has since retired. ESA's remaining two astronauts were both active in 1993-1994 with Claude Nicollier making his second flight on the Hubble servicing mission (STS-61) and Jean-Francois Clervoy making his first trip into space on STS-66 for the ATLAS

TABLE 3.1 MAJOR EURASIAN ELEMENTS OF ISS.

COUNTRY/ORG.	ELEMENT	EST. MASS (MT)	LAUNCH VEHICLE	LAUNCH YEAR
RUSSIAN FEDERATION	FGB	19.4	PROTON-K	1997
	SERVICE MODULE	20.7	PROTON-K	1998
	ACRV (SOYUZ-TM)	7.1	SOYUZ-U2	1998
	PROGRESS-M	7.3	SOYUZ-U/U2	1998
	PROGRESS-M2	12.8	ZENIT-2	1998
	UNIVERSAL DOCKING MODULE	8.0	ZENIT-2	1998
	DOCKING COMPARTMENT	3.9	SOYUZ-U	1998
	SCIENCE POWER PLATFORM	7.6, 6.8	ZENIT-2	1998, 1999
	SPP SOLAR ARRAYS	7.6, 7.0	ZENIT-2	1999, 2001
	RESEARCH MODULE #1	8.0	ZENIT-2	1999
	DOCKING STOWAGE MODULE	8.0	ZENIT-2	2000
	RESEARCH MODULE #2	8.0	ZENIT-2	2000
	LIFE SUPPORT MODULE	8.0	ZENIT-2	2000
	RESEARCH MODULE #3	8.0	ZENIT-2	2001
JAPAN	JEM PRESSURIZED MODULE	16.4	STS	2000
	JEM EXPOSURE FACILITY	13.4	STS	2000
ESA	ATTACHED PRESSURIZED MODULE	10.0	ARAINÉ 5	2001

## NOTES:

MT = METRIC TONS

FGB IS BEING PROCURED BY USA AND WILL BECOME AN AMERICAN ELEMENT

ACRV, PROGRESS-M, AND PROGRESS-M2 WILL BE FLOWN NUMEROUS TIMES; DATE INDICATES FIRST FLIGHT

TWO MISSIONS ARE REQUIRED FOR BOTH THE SPP AND THE SPP SOLAR ARRAYS

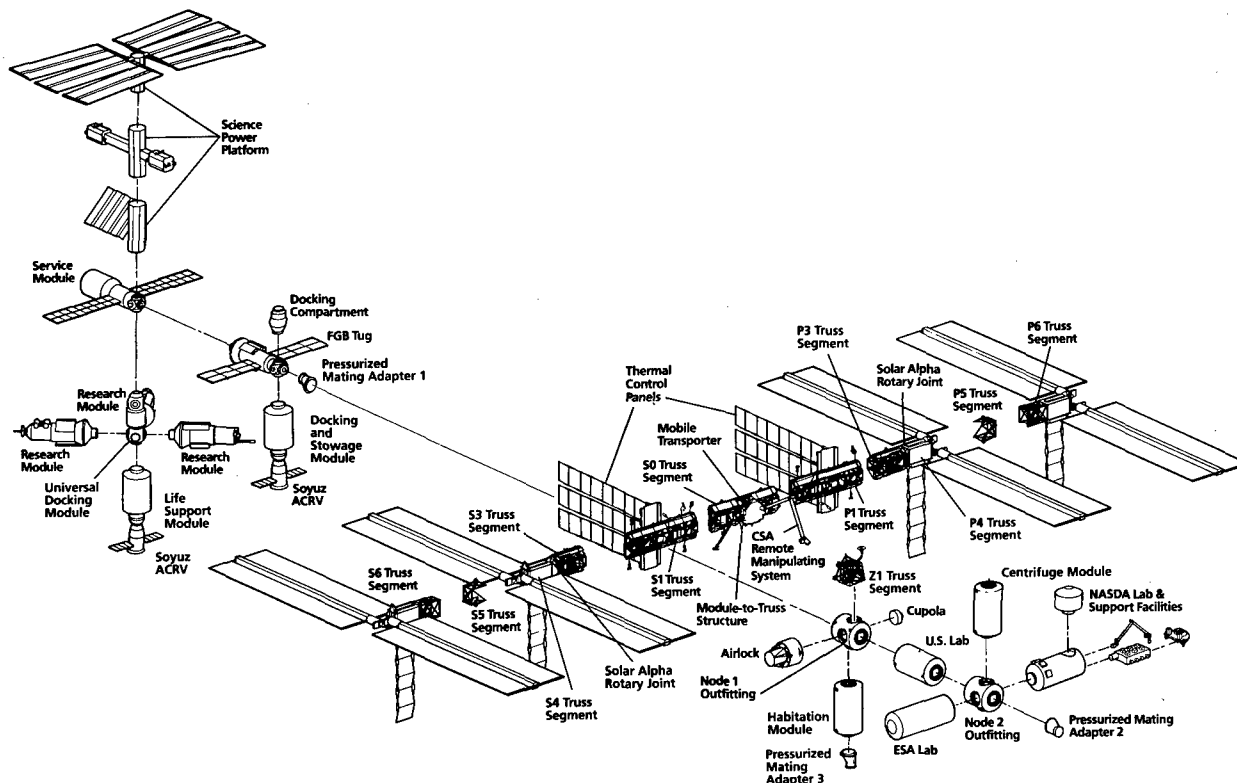


FIGURE 3.3 ELEMENT BREAKDOWN OF INTERNATIONAL SPACE STATION.



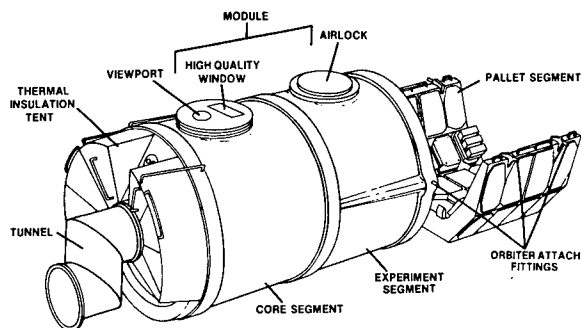


FIGURE 3.4 BASIC SPACELAB CONFIGURATION.

3 Spacelab mission. A Belgian member of ESA's ESTEC, Dirk Frimout, was also a member of the ATLAS 1 Spacelab crew on STS-45 (1992).

Clervoy, formerly a French astronaut trainee, was the first of ESA's 1992 selection class to fly in space (Reference 19). Maurizio Cheli (Italy) is scheduled to be on board STS-75 with Nicollier in 1996, while Thomas Reiter (Germany) was chosen for the second ESA mission to the Mir space station, Euromir 95, in

1995. Three other ESA trainees are still awaiting their assignments: Pedro Duque (Spain), Christer Fuglesang (Sweden), and Maraine Cheli-Merchez (Belgium).

Under the former Freedom Space Station program, ESA had committed to providing the Columbus attached laboratory with a mass of up to 23 metric tons, a length of 12 m, and a diameter of 4.5 m. Following the 1993 redesign of the International Space Station, ESA revamped their proposed contribution to the station, now called the Columbus Orbital Facility (COF), primarily to reduce cost. The module (Figure 3.5) will be shorter than the original design, relying heavily on the Mini Pressurized Logistics Module (MPLM) being produced by Italy for the US. The COF is now expected to have an initial mass of only 10 metric tons with a capacity to support four International Standard Payload Racks (ISPRs) and will be launched by an Ariane 5 booster in 2001. Formal approval for the construction of COF, along with details of the final design were expected in 1995 (References 20-27).

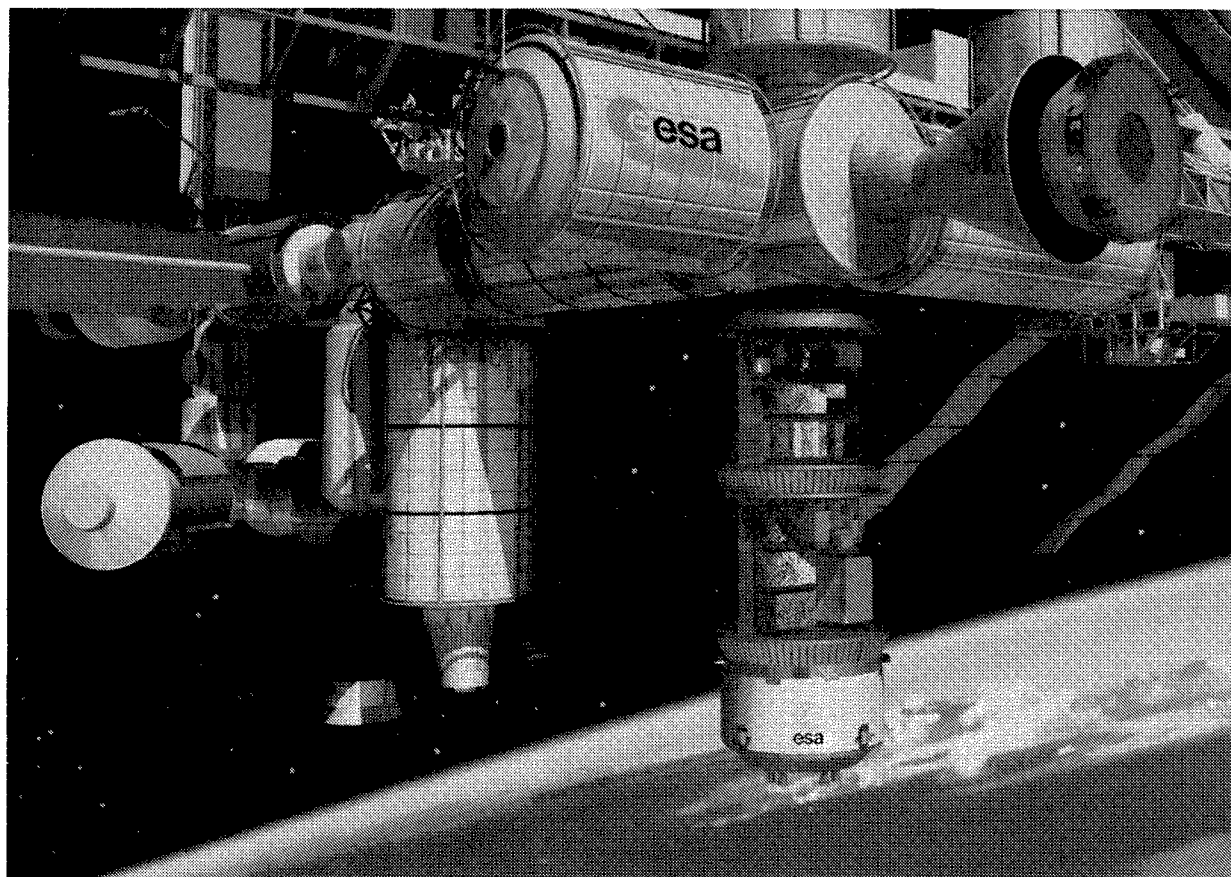


FIGURE 3.5 ESA CONCEPTS FOR COLUMBUS ORBITAL FACILITY, ATV, AND CTV.

While support for the Columbus program wavered during 1993-1994, renewed efforts to create Ariane 5-compatible manned and unmanned transports to service the space station were led by the French. Long-interested in providing an assured crew return vehicle for the space station, ESA initiated a new design effort for a manned spacecraft called the Crew Transport Vehicle or CTV (Figure 3.6). If developed, the 10-metric-ton CTV could carry a crew of four as well as a small amount of cargo to and from the International Space Station. The test of the Atmospheric Reentry Demonstrator (ARD) on the second Ariane 5 mission (scheduled for 1996) will set the stage for a possible CTV go-ahead in 1997 with an unmanned maiden flight in 2001. The ARD will have a mass of 2.8 metric tons, a diameter of 2.8 m, and a height of 2.4 m and will be produced by a team led by Aerospatiale (References 21, 28-36).

On a parallel path, ESA has been designing an Automated Transfer Vehicle or ATV for several years. The latest design of the ATV (Figure 3.7) envisions maximizing the use of Ariane 5 hardware to create a simple carrier with both pressurized and unpressurized

compartments and a cargo capacity of 10 metric tons or more. A detailed, 18-month definition phase was started in mid-1994. Success with the ATV is expected to encourage an ESA decision to proceed with the CTV (References 21 and 28).

In addition to the Euromir missions of 1994 and 1995, ESA and the Russian Federation explored several areas of potential collaboration during 1993-1994. However, most of these endeavors were associated with the planned Mir 2 space station which was later integrated into the International Space Station program, and consequently most of the efforts have been reoriented or abandoned. ESA and the Russian Federation had begun work on the design of a new EVA suit (EVA Suit 2000) which would be available near the turn of the century for Mir 2 and the now-canceled Hermes spaceplane. Other activities included modernization of the Soyuz TM and Progress M spacecraft, the development of a space station database management system, and the manufacture of an external robotic arm. The last two concepts remain candidates for the International Space Station (References 21, 37-44).

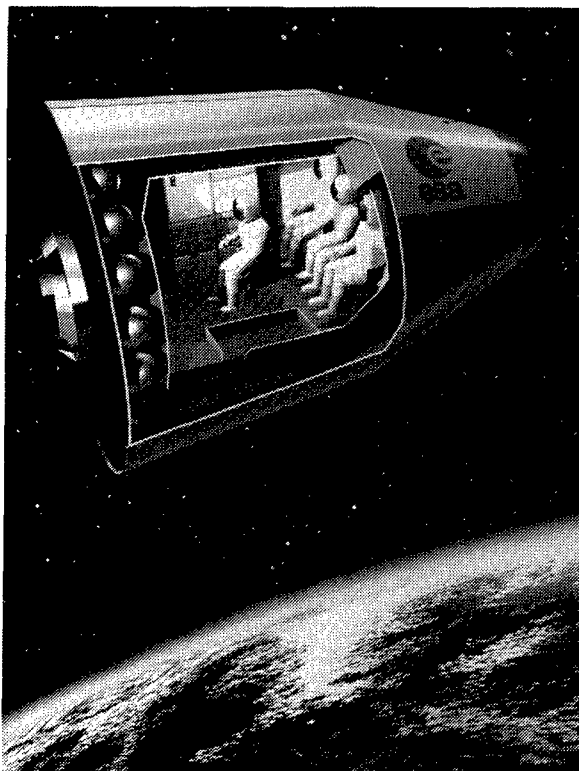


FIGURE 3.6 PRELIMINARY DESIGN FOR ESA'S CREW TRANSPORT VEHICLE.

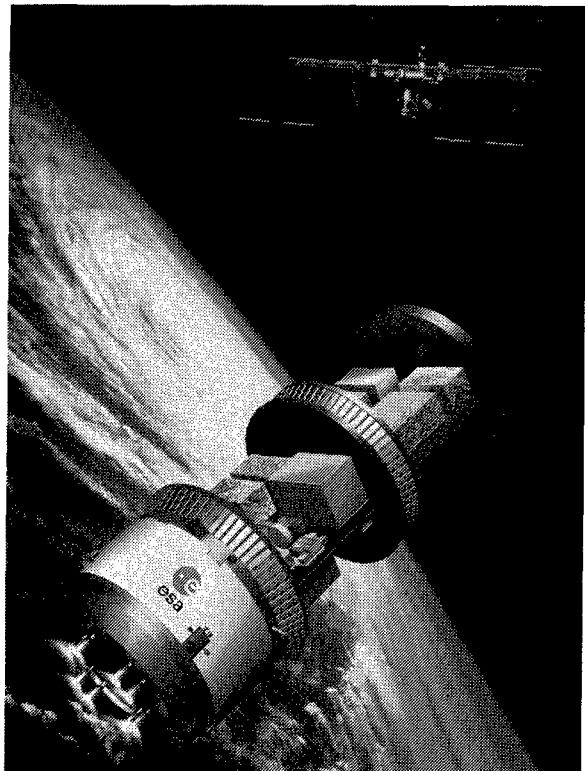


FIGURE 3.7 PRELIMINARY DESIGN FOR ESA'S AUTOMATED TRANSFER VEHICLE.

### 3.3 FRANCE

Between 1982 and 1994 five Frenchmen flew on six orbital missions conducted by the US or the USSR/Russian Federation (Appendix 3). All but one of these flights were nationally sponsored, whereas the last in 1994 was under the auspices of ESA. France was the originator of the Hermes spaceplane concept which was adopted and later abandoned by ESA and has been the principal proponent of ESA's CTV now under consideration for manned missions in the year 2002 or beyond. Meanwhile, France is preparing for two final short-duration missions to Mir in 1996 and 1997, respectively.

France's first astronaut, Jean-Loop Chretien, visited the Soviet Salyut 7 space station in June, 1982, on an 8-day mission and then worked on board Mir for 23 days during November-December, 1988. On the latter mission Chretien became the first non-American/non-Soviet astronaut to perform an EVA. In between Chretien's missions, Patrick Baudry was a member of the ST5-51G crew in 1985. During July-August, 1992, Michel Tognini spent nearly two weeks on board Mir under the Antares program, which was followed by the 3-week Altair mission to Mir of Jean-Pierre Haignere in July, 1993 (Section 3.8). Representing ESA, Frenchman Jean-Francois Clervoy flew on board STS-66 in 1994 (References 45-46).

Current plans call for Claudie Andre-Deshays to visit Mir in 1996 on board Soyuz TM-24 and for Leopold Eyharts to follow suit on Soyuz TM-27 in 1997. Both flights will last only about two weeks. The proposed decommissioning of the Mir space station in late 1997 or 1998 will probably negate earlier plans for another French mission to a Russian space station late in the decade (References 47-49).

### 3.4 GERMANY

Excluding the former Soviet Union, Germany can boast of the largest number of astronauts in Europe and Asia. By the end of 1994 seven German nationals had flown in space: six on German-sponsored missions on the US STS or Russian space stations and one as a representative of ESA (Appendix A3). Germany's experience with manned space flight dates back to 1978 when East German cosmonaut Sigmund Jahn became the third foreign national to visit a Soviet space station

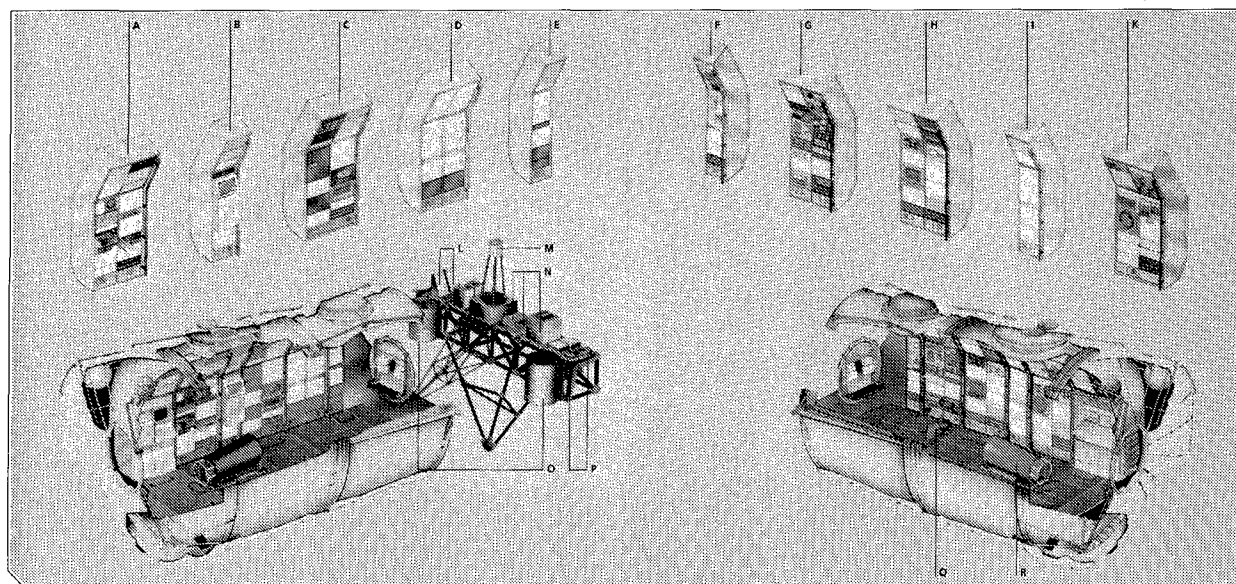
(Salyut 6). Moreover, five of these astronauts are physicists by profession rather than the more common pilot or engineer. During 1993-1994 the second German Spacelab mission, Spacelab D2, was conducted with the assistance of two rookie German astronauts, and Ulf Merbold completed his third flight in space for ESA under the Euromir 94 project.

A strong supporter of ESA's Spacelab program, Germany is the only ESA member to underwrite a dedicated Spacelab flight. The Challenger accident which occurred only a few months after the successful Spacelab D1 of October-November, 1985, with two German astronauts, delayed the continuation of such missions from 1988 until 1993. Spacelab D2, with German astronauts Hans Schlegel and Ulrich Water accompanied by five NASA astronauts, was launched on 26 April 1993 for an intensive 10-day mission of scientific studies. Figure 3.8 illustrates the primary facilities available to the crew, amounting to a payload mass of approximately 6.5 metric tons. Materials science and biological science experiments constituted the majority of planned activities, but Earth observation, atmospheric physics, astronomy, and technology research programs were also undertaken. Noteworthy experiments included the Robotic Technology Experiment (ROTEX), Modular Optical Multispectral Scanner 02 (MOMS 02), Galactic Ultra-wideangle Schmidt System (GAUSS), Atomic Oxygen Exposure Tray (AOET), Holographical Optical Laboratory (HOLOP), and Statolithic Experiment II (STATEX II) (References 50-53).

While a third German Spacelab mission was considered, no commitments have been made, and the prospect is now unlikely. German man-related activities will probably be restricted to international STS missions like IML or ESA-sponsored flights. Germany will continue its leadership of ESA's participation in the International Space Station program. Earlier plans to create a manned space transportation system Sanger/HORUS (Hypersonic Orbital Reusable Upper Stage) have been deferred indefinitely (Section 2.2).

### 3.5 KAZAKHSTAN

Although Kazakhstan has yet to establish a formal man-in-space program, Five of its natives have flown in space, accumulating more



The experimental facilities inside Spacelab are contained in racks, similar in concept to those used in ground laboratories

**A**  
SYSTEM RACK  
– on-board TV system  
– water cooling system  
– vacuum measurement system  
– cooler for BIOLABOR (see H)

**B**  
ROTEX RACK  
(Robotic Technology Experiment)  
– remote controlled robot arm  
– working cell

**C**  
MATERIAL SCIENCES LABORATORY  
– High Temperature Thermostat  
– Furnace for Turbine-blade geometry specimens  
– Isothermal Heating Furnace  
– Fluid Physics Module  
– Gradient Heating Furnace  
– Cryostat

**D**  
STORAGE RACK  
– Payload parts and samples  
– Spacelab system parts  
– Dosimeter for cosmic radiation

**E**  
EXPERIMENT RACK  
– Baroreflex (Blood pressure equipment with cardiac reflex measurement)  
– Microgravity measurement apparatus  
– Storage space for small parts

**F**  
EXPERIMENT RACK  
– Holographic Interferometer  
– Dosimeter for cosmic radiation  
– Video Monitor

**G**  
ANTHRO RACK  
(Human Physiology Laboratory)  
– Respiratory Monitoring System  
– Echo-cardiograph  
– High Speed Centrifuge  
– Blood Pressure Measurement Systems  
– Blood Sample Instrumentation  
– Ultrasonic Measurement Apparatus

**H**  
BIOLABOR  
– Electrolution of Cells  
– Cell Cultivation  
– Botany Experiments  
– Zoological Experiments

**I**  
STORAGE RACK  
– Payload parts and samples  
– Spacelab system parts  
– Dosimeter for cosmic radiation

**K**  
MEDEA  
(Material Sciences Experiment modules and Apparatus)  
– Elliptical Mirror Furnace  
– Gradient Furnace with fast sample cooling  
– High Precision Thermostat

**L**  
Exposure Facility with material samples

**M**  
Galactic Ultra-wideangle Camera (GAUSS)

**N**  
Modular Opto-electronic Multispectral Scanner

**O**  
Containers with independent material sciences experiments

**P**  
Biological Samples for investigation of Cosmic and UV radiation

**Q**  
Bicycle Ergometer

**R**  
Lower Body Negative Pressure Device

FIGURE 3.8 SPACELAB LAYOUT FOR GERMAN SPACELAB D2 MISSION.

than 650 man-days of experience. T.O. Aubakirov in 1991 was the fourth Kazakh to be launched into space but was the first to officially represent his homeland rather than the Soviet Union in general (Appendix 3). Two Kazakh astronauts, T.A. Musabayev and A.S. Viktorenko, conducted missions on the Mir space station during 1994 under the Soyuz TM-19 and Soyuz TM-20 programs, respectively. Specific activities and achievements of these Kazakh astronauts are summarized in Section 3.8.

### 3.6 JAPAN

Japan's entrance into manned space flight is following the road pioneered by its European allies: initial missions on foreign spacecraft, participation in the International Space Station program, and preliminary research on the development of a small, reusable spaceplane. Three Japanese have flown in space, but in general national support in Japan for manned activities has not yet matched that of Europe. A piloted version of the HOPE space

transportation system still awaits government approval.

Although the first Japanese astronaut, T. Akiyama, flew a mission to the Mir space station in late 1990 (Soyuz TM-11), this was a purely commercial venture, like the UK mission five months later, and did not enjoy government backing. The first officially sanctioned Japanese manned space flight occurred in September, 1992, on the US STS under the Spacelab J program, analogous to the German Spacelab D flights. The 8-day Spacelab J mission with astronaut M. Mohri was primarily devoted to conducting material sciences and life sciences experiments. Japan also played a major role in organizing the International Microgravity Laboratory program which first flew on the US STS in 1992 and was repeated in 1994. The latter mission included Dr. Chiaki Naito-Mukai as a payload specialist and the first Japanese female astronaut on the 15-day flight. A medically oriented STS mission with a Japanese astronaut is tentatively scheduled for February, 1998. Meanwhile, Koichi Wakata will

be a member of the STS-72 crew in 1995 on a mission to retrieve the Japanese Space Flyer Unit (References 54-55).

The Japanese Experiment Module (JEM) was designed to serve as one of the four primary sections of the Freedom Space Station and has remained essentially unchanged in the current design for the International Space Station. JEM is actually a complex facility consisting of a Pressurized Module, Experiment Logistics Modules (Pressurized Section and Exposed Section), an Exposed Facility platform, an air-lock, and a remote manipulator arm (Figure 3.9). The Experiment Logistics Modules and the Exposed Facility are specifically designed to be replaced periodically to allow a diverse and evolutionary scientific experimentation program. Under current plans JEM will be delivered to the International Space Station in parts in the year 2000. When fully assembled, the module will probably possess a mass in excess of 30 metric tons. The engineering model of JEM was already under construction by the end of 1992, and in December, 1993, the Space Station Test Building was completed. Thermal tests on the structural model of JEM's Exposed Facility began in July, 1994. NASDA is managing the JEM program with the assistance of prime contractor Mitsubishi Heavy Industries. The Japan Manned Space Systems consortium has also been formed to promote a long-term presence in space (References 56-64).

NASDA had planned to make HOPE a vital part of JEM's logistical infrastructure. Launched by the H-II booster, HOPE (Section 2.6) would deliver new equipment to the space station and return with the fruits of scientific experiments.

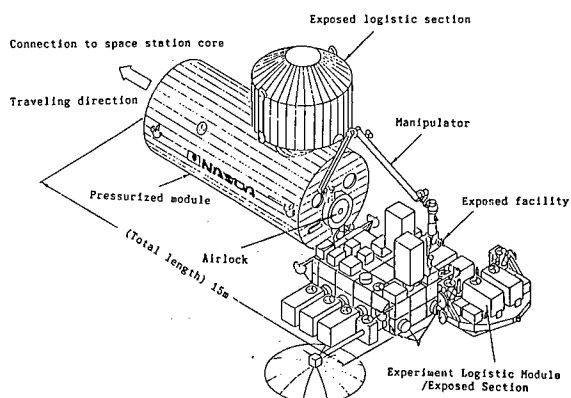


FIGURE 3.9 JAPANESE EXPERIMENT MODULE FOR ISS.

This scenario is still possible if the program is approved later in the decade, but a manned version of the spaceplane is unlikely until about 2010 or later.

### 3.7 PEOPLE'S REPUBLIC OF CHINA

Since the late 1970's the PRC has seriously planned for the eventual flight of Chinese astronauts, but shifting program priorities have resulted in only preliminary work in the areas of spacecraft design and space medicine. Small teams of Chinese have undergone some astronaut training, and designs for manned spacecraft ranging from simple capsules to space shuttles to space stations have all been drawn up. The 1984 prospect of a Chinese astronaut flying on the US Space Shuttle never materialized (Reference 65).

A 1978 decision to embark on a Chinese manned space program was short-lived, although astronaut training and space suit design were initiated (References 66-70). By the mid-1980's PRC began to talk about building a manned Chinese space station in apparent competition with the US and the USSR programs (References 71-76). Although discussions of sophisticated space shuttles were offered, the near-term goal appeared to be a Gemini-class capsule launched by an expendable booster with a crew of 2-4 astronauts. In 1994 the PRC held discussions with Russian aerospace officials for the purpose of acquiring Soyuz technology to be adapted to a Chinese recoverable capsule for launch by a CZ-2E booster, perhaps as early as the year 2002. The launch site may be a new facility reported in 1992 to be under construction 200 km from Jiuquan (References 77-82).

The PRC has also renewed its interest in joining the International Space Station, although such cooperation is unlikely before the facility reaches its initial full operational capability in 2002 (References 83-84). Plans for a Sanger-class, two-stage manned space shuttle were under development in the early 1980's, but the demanding program does not appear to have a high priority (Reference 85).

### 3.8 RUSSIAN FEDERATION

The Mir space station program celebrated its eighth anniversary of orbital operations in 1994 amid growing international interest in exploiting the facility before construction of the International Space Station begins in late 1997.

In fact, Phase 1 of the ISS program revolves around seven missions during 1995-1997 when a US Space Shuttle will dock with the Mir space station. Meanwhile, ESA and French missions to Mir will continue under separate agreements. The Mir program is now set for termination in 1998 but may be extended.

The Mir core module has been in Earth orbit since February, 1986, and by the end of 1994 had exceeded its original design life. The vehicle is 13.1 m long with a maximum diameter of 4.2 m and an initial mass of 20.4 metric tons. The habitable volume is approximately 90 m<sup>3</sup>, and the two main solar arrays were augmented in 1987 with a third, deployed array for a total power capacity of 10.1 kW, although environmental effects have reduced this value. The basic outward configuration of Mir was similar to that of Salyut 6 and Salyut 7, but the forward transfer compartment of Salyut was replaced with a 5-port docking module on Mir. Internally, many design changes and system improvements were incorporated.

Space station logistical and upgrade requirements have been met with three classes of spacecraft: crew ferries (Soyuz T and Soyuz TM), unmanned cargo ships (Progress and Progress M), and large specialized modules (Kvant and Kristall). By the end of 1994, Mir had received one Soyuz T, 20 Soyuz TM, 18 Progress, and 25 Progress M spacecraft as well as three large, permanent modules: Kvant 1, Kvant 2, and Kristall. Impressively, all 68 of

these spacecraft, representing about 540 metric tons, were launched successfully and achieved their primary objectives of docking and crew and cargo deliveries.

Designed and manufactured by RKK Energiya, the Soyuz TM is capable of carrying three cosmonauts and has a gross weight of just over seven metric tons, a length of seven meters, and a maximum diameter of 2.7 m (Figure 3.10). The spacecraft consists of three main sections: the orbital module, the command and reentry module, and the service module. Two solar arrays (10.6 m span) provide electrical power for the typical 50-hour journey to Mir and can be interconnected with the space station's electrical system to furnish an additional 1.3 kW. The nominal flight time for a Soyuz TM spaceship is 5-6 months (References 86-90).

Since the cargo capacity of a manned Soyuz TM is limited to only a few hundred kilograms, a more efficient logistics vehicle was designed for support operations to Mir. Progress M (maiden flight in August, 1989) is a "modernized" version of the original Progress cargo freighter (1978-1990) which flew 43 times (including Kosmos 1669) without a docking failure. Derived from Soyuz TM, Progress M has a launch mass of approximately 7.3 metric tons and a length of 8.2 m.

Whereas the service module is essentially the same as the one used by Soyuz TM, the central module is designed for carrying

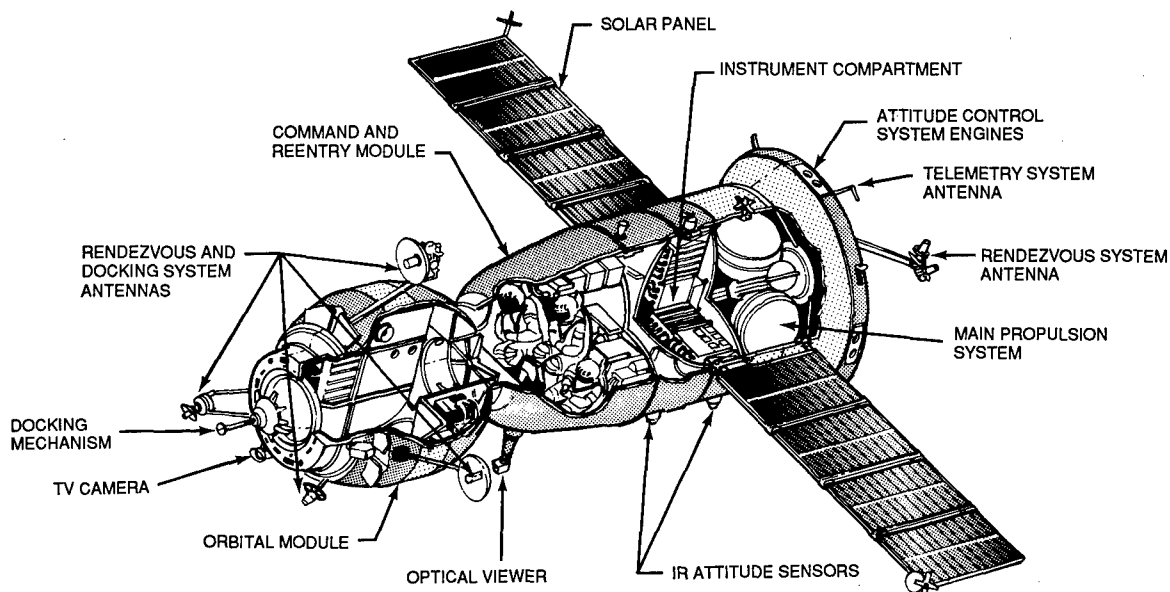


FIGURE 3.10 SOYUZ TM SPACECRAFT.

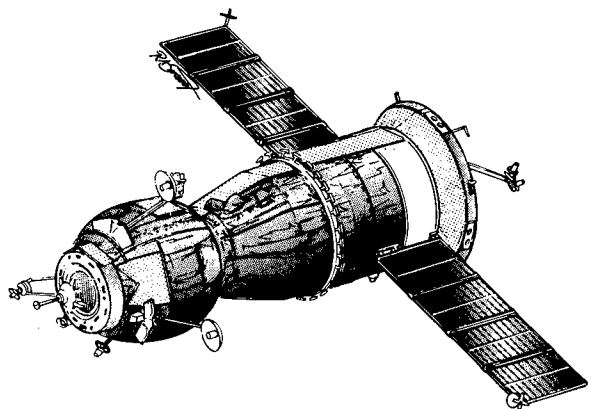


FIGURE 3.11 PROGRESS M SPACECRAFT.

propellants, air, and water, while dry cargo is stored in the forward, nearly spherical compartment (Figure 3.11). Continual improvements to the spacecraft have increased the total payload cargo to 2.7 metric tons, although the use of the Soyuz-U launch vehicle instead of the Soyuz-U2 since mid-1993 has generally limited the cargo capacity to 2.5 metric tons. Progress M was originally rated for 30 days independent flight and up to 180 days attached to Mir. During 1993-1994 Progress M-17 established new records with a 131-day stay at Mir and a total flight time of 337 days. Although Progress M spacecraft are destroyed during reentry, beginning in 1990 (Progress M-5) a small Raduga recoverable capsule (payload capacity of 150 kg) has been used on about every other mission (References 87, 89-95).

With the advent of the Mir space station in 1986, a new requirement for permanent expansion of the orbital complex was set. In 1987 Kvant 1, a specialized module left over from the Salyut 7 program, was attached to Mir not only to provide a complex set of scientific equipment (the international Roentgen X-ray Observatory consisting of the HEXE, Pulsar X-1, Sirene-2, and TTM instruments; the Glasar UV telescope; and the Svetlana electrophoresis unit) but also to enhance space station support systems, in particular attitude control via six large gyrodynes. When attached to the aft docking port of Mir, Kvant 1 measured 5.8 m in length and 4.2 m in diameter with an initial mass of 11 metric tons (References 87, 89-90, 96-97).

The four forward radial ports were reserved for full-size modules of about 19.6 metric tons each. The highly specialized modules were built

at the Khrunichev Machine Building plant for the Energiya NPO, now RKK Energiya. Kvant 2, which was attached in 1989, was also known as the additional equipment module in accordance with its wide variety of new systems. Perhaps the most important feature of the new module was the unique air-lock chamber with an enlarged (1 m diameter) exit hatch. In addition, the 12.4 m long, 4.4 m diameter Kvant 2 housed the following major equipment:

- Six gyrodynes
- MKF-6MA multi-spectral camera system
- ITS-7D infrared spectrometer
- MKS-M2 optical spectrometer
- KAP-350 Topographic camera
- ARIS X-ray sensor
- Inkubator 2 hatchery
- Rodnik water system
- Elektron and Vika electrolysis units
- ASP-G-M exterior instrument platform.

Less exotic but equally important are Kvant 2's two solar arrays with a capacity of 6.7 kW at beginning of life (References 87, 89-90, 98-103).

Six months after the arrival of Kvant 2, the Kristall module became the newest component of the Mir complex. Kristall possessed the same mass and diameter as Kvant 2 but was a little shorter at 11.9 m. In place of the Kvant 2 air-lock chamber, Kristall was equipped with a new multiple docking adapter employing two APAS-89 androgynous ports for mating with the Buran space shuttle and a new model of Soyuz TM.

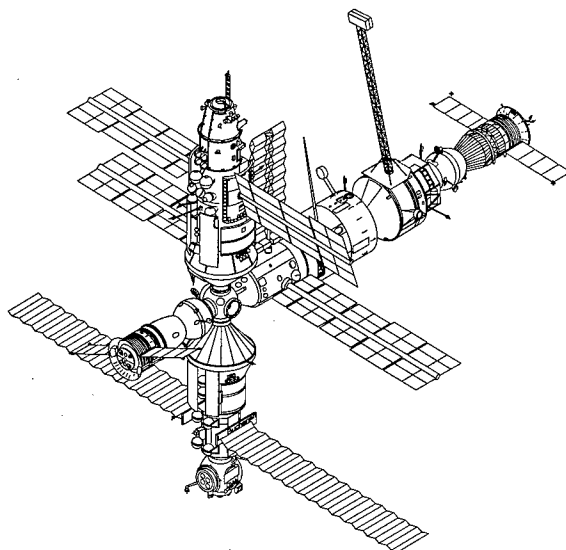


FIGURE 3.12 MIR SPACE STATION CONFIGURATION, JANUARY, 1993.



The primary scientific payload was devoted to microgravity research and is described in more detail in Section 4.4.7. Kristall also carried the Priroda 5 high resolution camera and the Svet greenhouse for botanical research. The two solar arrays on Kristall were of a new design with a total 8.4 kW capacity, variable deployment positioning, and the ability to be removed and relocated to another part of the space station (References 87, 89-90).

By the end of 1990 the Mir space station's normal configuration consisted of six linked spacecraft: Mir, Kvant 1, Kvant 2, Kristall, a Soyuz TM, and a Progress M. Together they boasted a total mass of about 90 metric tons and a habitable volume of 270 m<sup>3</sup>. With further additions installed during EVAs, the complex at the end of 1992 appeared as shown in Figure 3.12. Detailed interior drawings of the four main modules are presented in Figures 3.13 and 3.14 (Reference 108).

### 3.8.1 1993 Operations

As the new year of 1993 dawned, the twelfth expedition to Mir was drawing to a close. Cosmonauts Anatoli Y. Solovyev and Sergei V. Avdeyev had docked their Soyuz TM-15 spacecraft at Mir on 29 July 1992 along with French cosmonaut M. Tognini, who had returned to Earth on 10 August 1992 with the Soyuz TM-14. Also attached to Mir was the Progress M-15 cargo spacecraft which had arrived at the space station on 29 October 1992. The entire complex was circling the Earth at a mean altitude of 395 km with an orbital inclination of 51.6°. The schedule for 1993 drawn up by the Russian Space Agency called for three new expeditions as well as five Progress M logistical missions (Reference 109).

During the first three weeks of January, Solovyev and Avdeyev conducted a variety of geophysical and astrophysical observations and refueled the Mir core module with propellants

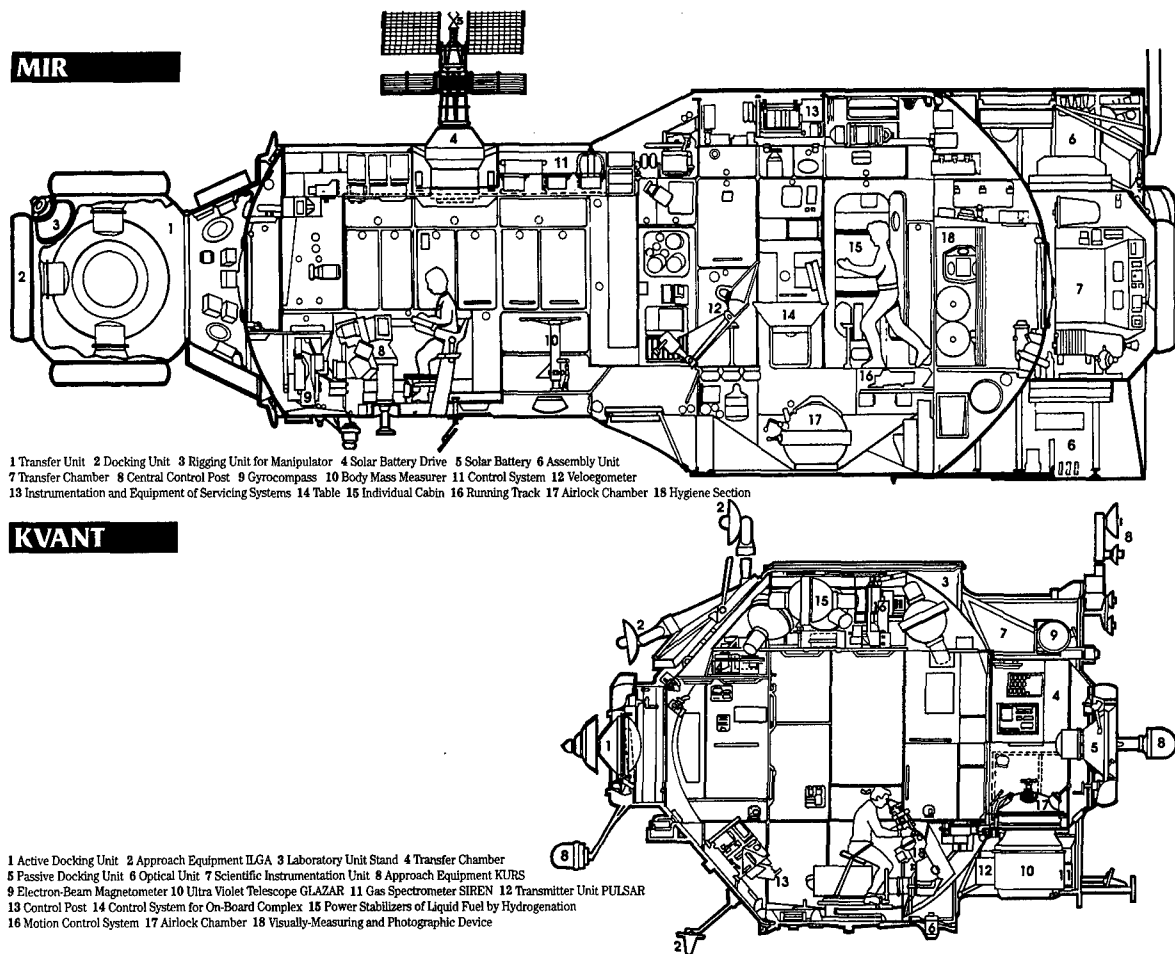
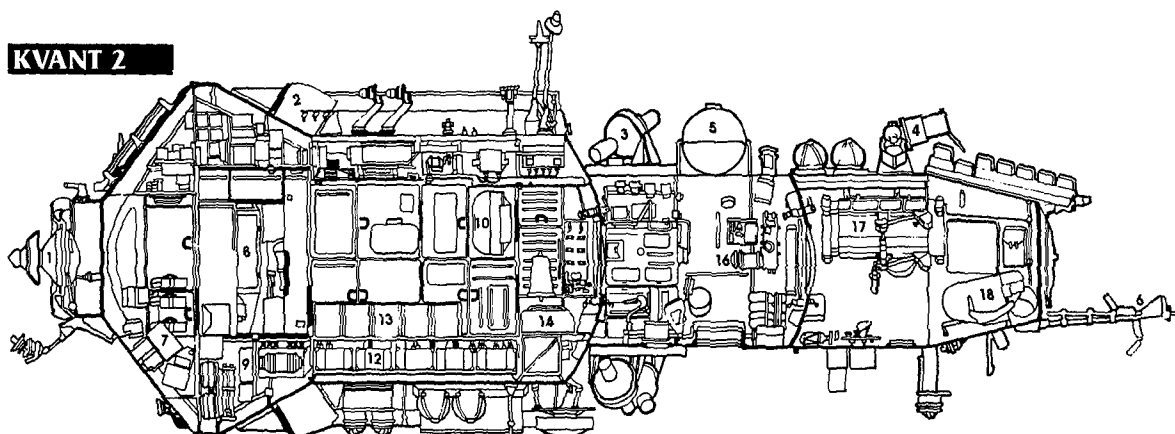


FIGURE 3.13 LAYOUT OF MIR AND KVANT 1 MODULES.

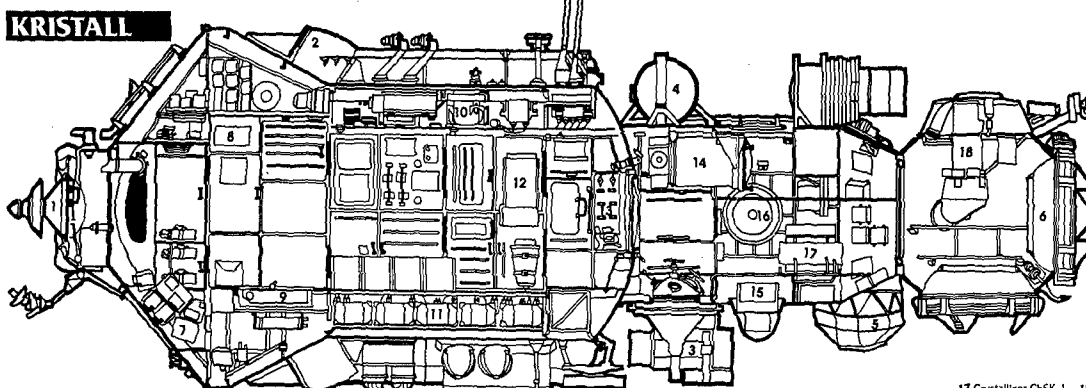


## KVANT 2



1 Active Docking Unit 2 Engine Installation 3 Power Stabilizers of liquid Fuel by Hydrogenation 4 Optical Star Transmitter 5 Tank Systems RODNIK 6 Exit Outlet 7 Control Post 8 Hygiene Cabin 9 Water Regeneration Systems 10 Portable Plumbing Unit 11 Motion Control System 12 Energy Supply System 13 Food Containers 14 Payload Container 15 Multi-Zonal Photo Camera 16 VIKOD Equipment 17 Cosmonaut Motion Equip. 18 Space Suit

## KRISTALL



1 Active Docking Unit 2 Engine Installation 3 Telescope GLAZAR 2 4 Tank System RODNIK 5 Instrumentation MARINA 6 Androgynous-Peripheral Docking Assembly 7 Control Post 8 ONIKS Panel for the KRATER V 9 Running Track 10 Motion Control System 11 Energy Supply System 12 SVET Arrangement 13 RODNIK System Panel Armature 14 Freezer 15 KSENIA Device 16 Reusable Solar Battery Drive 17 Crystallizer ChSK-1 18 PRURODA-5

FIGURE 3.14 LAYOUT OF KVANT 2 AND KRISTALL MODULES.

from Progress M-15. Meanwhile, final preparations were being made on Earth for the launch of the Soyuz TM-16 spacecraft. Commander Gennady Manakov, a veteran of the 5-month Soyuz TM-10 mission, and Flight Engineer Aleksandr Poleshchuk, a rookie cosmonaut, arrived at the Baikonur Cosmodrome on 11 January along with their backup crew. The launch of Soyuz TM-16 occurred on schedule on 24 January with a planned docking at Mir 49.5 hours later (References 110-113).

Soyuz TM-16 differed from all its 15 predecessors by being equipped with the new APAS-89 (Androgynous Peripheral Docking Assembly) system designed specifically for docking with the forward port of the Kristall module. The device had originally been created to permit dockings between the Mir space station and the Buran space shuttle, and a Soyuz TM test flight had been repeatedly delayed since 1991. Although Buran was destined to never fly again, the test of the

APAS-89 system was vital to the proposed matings of Mir with US Space Shuttles.

As Soyuz TM-16 approached to within 150 m of the Mir space station on the morning of 26 January Manakov and Poleshchuk disengaged the automatic rendezvous and docking system to assume manual control during the final few minutes. The spacecraft was slowly brought to within 70 meters where a final maneuvering system check-out and visual survey of the Kristall port were performed. Approval for docking was then given, and Soyuz TM-16 docked without incident several minutes ahead of schedule. Not only had a spacecraft docked successfully with the special Kristall port, but also the Mir complex for the first time consisted of seven linked vehicles with a mass of approximately 100 metric tons (References 111, 113-115).

For the next six days the four cosmonauts were busy engaged in the traditional handover tasks and preparing the Soyuz TM-15

spacecraft for its return to Earth. A Rezonans experiment was conducted to evaluate the dynamic and structural characteristics of the new Mir configuration, and Solovyev and Avdeyev spent time wearing the Chibis pneumatic suit designed to improve circulation in the lower extremities prior to going home. After loading Soyuz TM-15 with experimental results and personal effects, Solovyev and Avdeyev entered their spacecraft, closed the hatches to Mir, and undocked precisely at the stroke of midnight (GMT) on the morning of 1 February. Three hours and 48 minutes later the duo had safely landed after a mission of nearly 187 days (References 116-117).

The Soyuz TM-15 post-mission review highlighted the achievements of the twelfth expedition which included four spacewalks (three for the installation of an attitude control unit on the Sofora girder) and experiments in a wide range of scientific disciplines. Of particular significance was the hatching of quail eggs in the Incubator-2 facility. On the other hand, the delay in launching the remaining two modules, Spektr and Priroda, to Mir and the increasingly frequent equipment breakdowns on the space station were also acknowledged as limiting the potential of the Russian man-in-space program. The new Soyuz TM-16 mission was assigned only moderate objectives, including up to three EVAs and the reception of three unmanned Progress M spacecraft. However, only a few days after assuming command of Mir, Manakov and Poleshchuk were to initiate an experiment of extreme scientific and engineering interest (References 118-120).

After a stay of 97 days, Progress M-15 was undocked from the Kvant 1 aft port early on 4 February, setting the stage for two final tasks. Twelve minutes after undocking and still at a distance of only 160 m, the Znamya (Banner) 2 solar reflector experiment commenced with the 3-minute unfurling of a 20-m diameter, circular Kevlar sheet from a special unit attached to the forward end of Progress M-15. An initial spin-rate of 95 rpm (later reduced to 14 rpm) kept the eight triangular sections relatively flat, forming a nearly uniform disk. The spacecraft was then reoriented to begin the "New Light" experiment four hours and 15 minutes after undocking and 12.1 km from Mir. For six minutes the reflector projected a spot up to 30 km in diameter onto the Earth, but the experiment was abruptly terminated when Progress M-15 crossed the

terminator into the sunlight portion of the Earth (Figure 3.15). Within minutes the Znamya apparatus was ejected from the spacecraft to permit another experiment the following day. Future experiments involving protracted illumination of regions of the Earth and solar sail propulsion have been proposed, although funding appears to be lacking (References 116, 121-130).

On 5 February Progress M-15, under command of the Flight Control Center (FCC or TsUP) outside Moscow, was maneuvered back toward the Mir space station. At a distance of 200 m the cosmonauts on Mir took control of the cargo craft with a new teleoperator system and practiced guiding the spacecraft manually. Unbeknownst to Mir program managers, this successful test would later be highly valuable. Finally, on 7 February Progress M-15, its mission now over, was commanded to de-orbit after which it was destroyed during reentry into the atmosphere (Reference 131).

For the next two weeks Manakov and Poleshchuk tended to less dramatic chores and experiments, including medical checks and exposures of materials to outer space. A new resupply spacecraft, Progress M-16, was

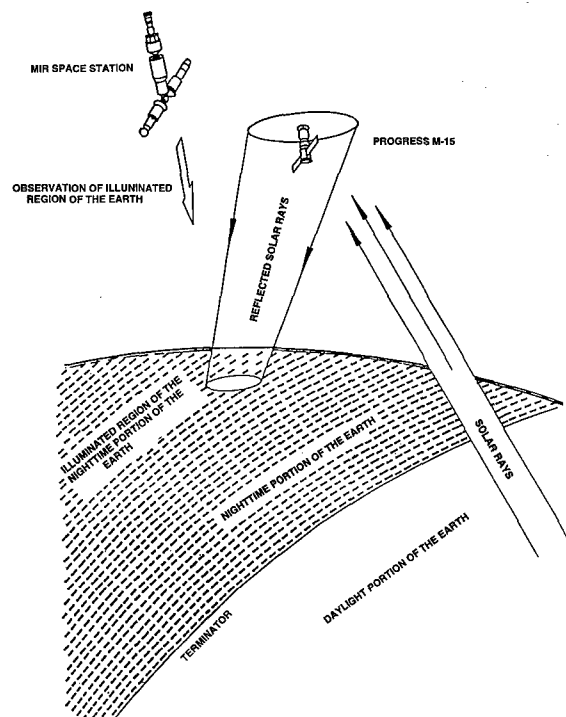


FIGURE 3.15 SCHEMATIC DIAGRAM OF ZNAMYA EXPERIMENT.

launched on 21 February, docking with the Kvant 1 aft port on schedule two days later with nearly 2.6 metric tons of needed material. During the following four weeks the Mir crew performed a series of maintenance tasks, including the replacement of a faulty air-conditioning unit and a communications system regulating contact with the Luch geostationary data relay satellite, work on the atmospheric water extraction system, and installation of new gyrodyne stabilizers in the Kvant 2 module. Meanwhile, propellant was transferred from Progress M-16 to Mir, and the former's propulsion system was used to make the first of several orbital maneuvers for the space station during the 1993-1994 period (Figure 3.16) (Reference 132).

To expand upon the experience in remote control of a Progress M spacecraft gained during February, Progress M-16 was undocked on the morning of 26 March. Once again the cosmonauts took control of the robot vehicle, first backing it away from the orbital laboratory to a distance of 70 m and then guiding the spacecraft to a redocking with Kvant 1 after only 17 minutes. The following day Progress M-16 was undocked again under the control of Manakov and Poleshchuk, but control was quickly passed to the TsUP which commanded the vehicle into a destructive reentry into the atmosphere (Reference 133).

Flight control managers rarely leave Mir unattended by a Progress M spacecraft, so the launch of Progress M-17 on 31 March and its docking with Kvant 1 on 2 April were routine. The next major event on board Mir occurred on

19 April when Manakov and Poleshchuk conducted their first EVA of the mission. The objective was to transfer a solar array drive from the Kristall module to Kvant 1 in preparation for the later transfer of the entire solar array, a project which was already years behind schedule. The spacewalk, planned for a 4 hr 57 min duration, started well but ran into several problems.

The solar array drive was transferred with the aid of the Strela crane, but the cosmonauts experienced difficulty in completely installing the unit in its new location on Kvant 1. Poleshchuk's space suit was also indicating a problem in the ventilation system. Finally achieving their task, the two cosmonauts began returning to the EVA compartment of Kvant 2, only to discover that one of the two operating handles for the Strela crane had floated away. The EVA was safely concluded after 5 hr 25 min, but future EVAs were postponed until either a makeshift handle could be devised or a new handle could be delivered (References 134-136).

Activities on board Mir during the following month were uneventful, and a replacement handle could not be improvised. Therefore, when the next resupply ship, Progress M-18, was launched on 22 May (three days behind schedule), a new handle for the Strela crane was on board. Progress M-18 docked with the Mir forward port on 24 May while Progress M-17 remained attached to Kvant 1, thus marking the first time that two Progress spacecraft had ever been docked to a Soviet/Russian space station simultaneously. The reason for retaining

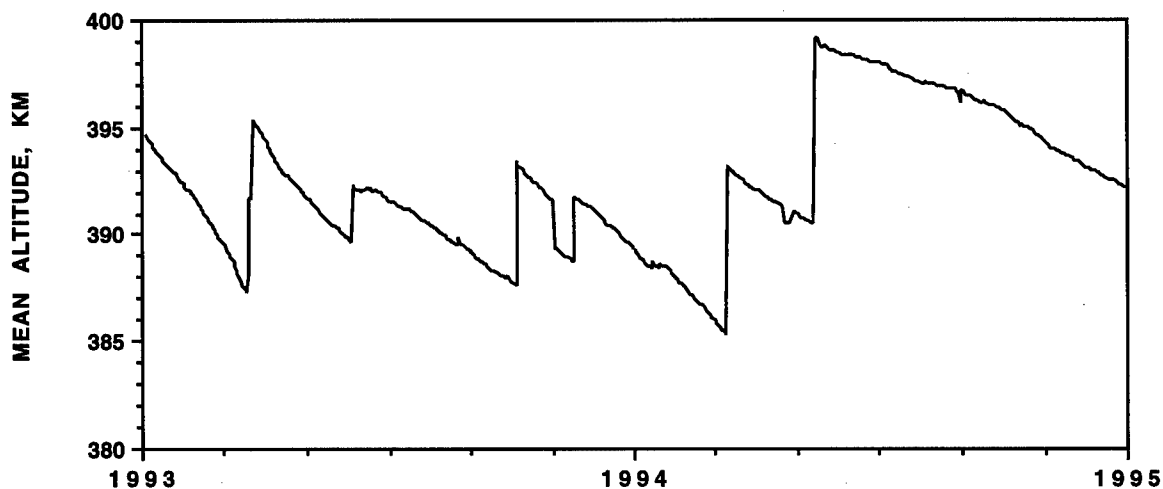


FIGURE 3.16 1993-1994 ORBITAL HISTORY OF MIR SPACE STATION.

Progress M-17 was not apparent until almost three months later. In addition to the Strela handle and the normal supplies, Progress M-18 also carried a 1-kg aluminum sculpture entitled Cosmic Dancer under a commercial agreement with a Swiss non-profit organization. The new Mir visitor was also the first Progress M spacecraft of the year to be equipped with a Raduga return capsule (References 137-140).

With the Strela replacement part now in hand, a second EVA was scheduled for 18 June. This time all went well, and the cosmonauts were able to fix the Strela crane and transfer the remaining Kristall solar array drive to Kvant 1. In fact, the entire operation lasted only 4 hr 33 min, less than the allocated 5 hours. For the rest of the month, Manakov and Poleshchuk were engaged in routine experiments and maintenance as they awaited the arrival of their relief crew (References 141-143).

The Soyuz TM-17 mission was to be the fourth French visit to a Soviet/Russian space station and would allow Air Force pilot Jean-Pierre Haignere a stay of nearly three weeks on Mir. In charge of the flight was Lt. Col. Vasilii Tsibliyev assisted by Flight Engineer Aleksandr Serebrov. Tsibliyev was making his first entry

into space, while his Russian comrade was a veteran of three previous missions. Lift-off occurred on schedule in the afternoon of 1 July, and a normal two-day rendezvous brought the Soyuz TM-17 spacecraft to the vicinity of the Mir complex on 3 July (References 143-147).

Mission managers took advantage of a rare photo opportunity as Soyuz TM-17 approached the space station. With both the standard docking ports occupied by Progress M spacecraft, one had to be vacated to give Soyuz TM-17 a berthing space. As the new manned spacecraft hovered nearby, Progress M-18 undocked and slowly backed away from the Mir forward port (Figure 3.17). Just 26 minutes later, Soyuz TM-17 had successfully docked in its place. Progress M-18 then continued in independent flight for another day before returning to Earth in a destructive reentry, but not before releasing its small Raduga capsule which was retrieved intact in the designated recovery region in Russia (References 143, 148-149).

This short French mission to Mir was code-named Altair and was designed to conduct biomedical and technical experiments, including the completion of two experiments started by Haignere's fellow countryman M. Tognini the

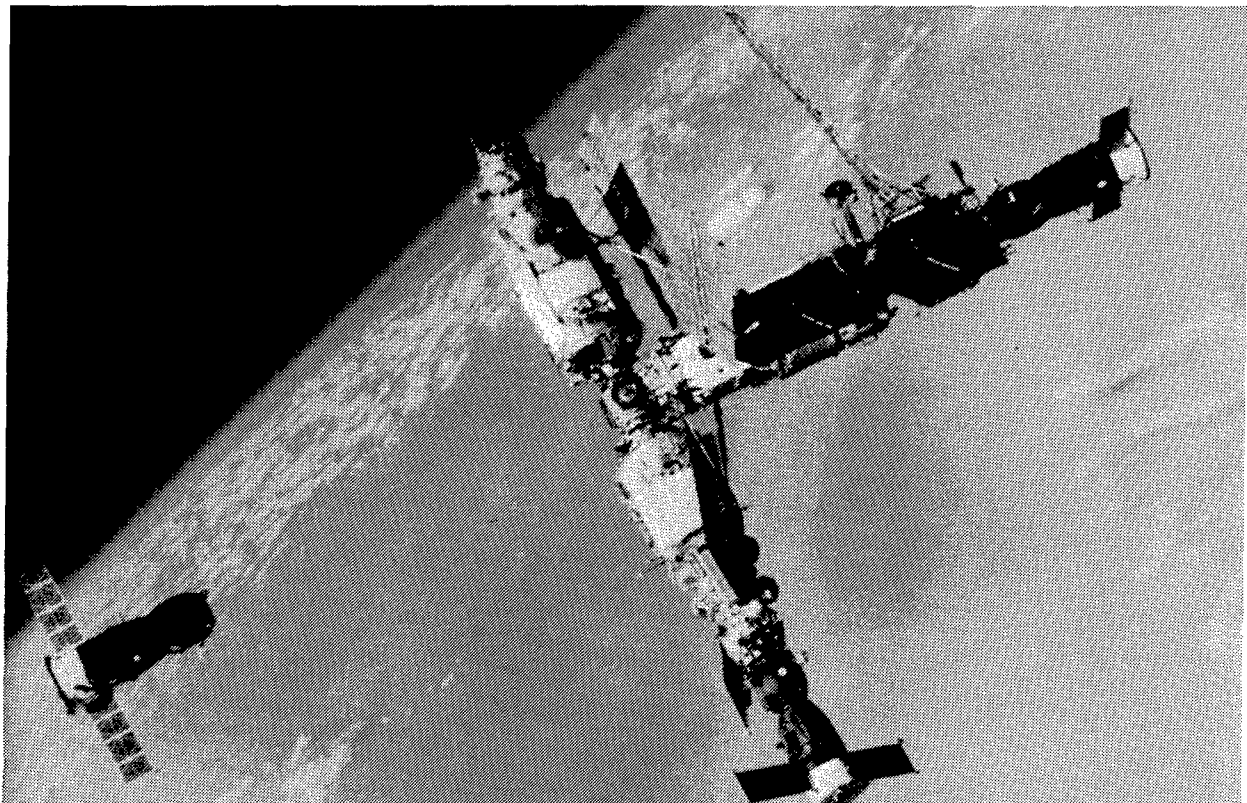


FIGURE 3.17 MIR COMPLEX ON 3 JULY 1993, TAKEN BY SOYUZ TM-17.

previous year (Soyuz TM-15). From 3 to 21 July the five cosmonauts were busily engaged in scientific studies and the preparation of the Soyuz TM-16 spacecraft for its return home. Manakov, Poleshchuk, and Haignere departed Mir in the early morning of 22 July and safely landed 140 km east of Dzhezkazgan in Kazakhstan (References 150-152).

The 14th expedition of Mir by Tsibliyev and Serebrov was originally planned to last only 147 days and to include three EVAs, but in reality both measures were increased. In early August a new Progress M logistics vehicle was being prepared as work with the long-term Progress M-17 resident was ending. Progress M-19 was launched on 10 August, and to make room for it Progress M-17 was finally undocked on 11 August after a stay of 131 days. However, instead of being recalled to Earth, Progress M-17 began a secondary mission of verifying the reliability of spacecraft systems, with emphasis on those also common to Soyuz TM spacecraft. When the International Space Station is operational, Soyuz TM spacecraft will serve as Assured Crew Return Vehicles (ACRVs) and will need design lifetimes of at least one year. Progress M-17 was maneuvered into an orbit 18 km below Mir on 12 August, the day Progress M-19 docked with the space station, and was allowed to decay naturally during the remainder of the year (References 153-155).

Just as Progress M-17 and Progress M-19 were changing places, the Mir space station was battered by numerous micrometeoroids originating from the annual Perseid meteor shower representing the remnants of Comet Swift-Tuttle. Tsibliyev and Serebrov retreated to their Soyuz TM-17 spacecraft and closed the hatches to permit a quick getaway if the station was severely damaged. Although a large number of hits on the station were noted, the most serious effects appeared to be holes in some of the solar arrays.

The next noteworthy event on Mir came a month later when the two cosmonauts performed a pair of EVAs to erect the Rapana truss on the Kvant 1 module. Rapana closely resembled the Sofora girder which was constructed in 1991 but was shorter with an extended length of only 5 m. The 26-kg structure was designed not only to test additional space construction techniques but also to serve as a site for future experiments, particularly the exposure of material samples to the near-Earth space

environment. During a 4 hr 18 min EVA on 16 September Tsibliyev and Serebrov transferred the stowed Rapana package to Kvant 1 and attached it to a base platform. Four days later the duo returned to erect the truss and to attach the first experiment cartridges during an EVA lasting 3 hr 13 min (References 156-160).

After resting for eight days, Tsibliyev and Serebrov prepared for their third and last planned EVA. The principal objective of this outing was simply to inspect and to photograph the exterior of the complex for the purpose of evaluating the effects of seven and one-half years in the harsh space environment. Upon exiting the Kvant 2 EVA compartment the cosmonauts attached a new cassette of samples for more exposure tests and retrieved an older unit. However, before the inspection of Mir could begin in earnest Tsibliyev's space suit began to overheat. Consequently, the EVA was terminated after only 1 hr 52 min without accomplishing the primary task (References 161-162).

October proved to be a significant month for the Soyuz TM-17 crew. Early in the month Russian officials announced that the launch of Soyuz TM-18 had been postponed until January, 1994, necessitating an extension to the current mission. The reason given for the change of plans was a delay in the preparation of a Soyuz-U2 launch vehicle. Since the next mission was to involve a three-man crew, use of the lower capacity, Soyuz-U booster was not a viable option. Unfortunately, the delay also meant that plans to keep one of the Soyuz TM-18 cosmonauts on-board Mir for 16 months had to be revised to only a 14-month stay (References 162-164).

Shortly after hearing the news of their involuntary extension, Tsibliyev and Serebrov prepared to receive yet another resupply ship. Progress M-20, carrying a commercial US biotechnology experiment, was launched on 11 October and docked at the Kvant 1 aft port two days later. Meanwhile, on 12 October Progress M-19 undocked from that port and returned a Raduga capsule to Earth about six hours later, early on 13 October. Back on Mir, the crew was initiating the newly delivered foreign experiment, which was to be returned in another Raduga capsule also brought by Progress M-20 (References 165-168).

On 22 October Serebrov set a new world record for the number of EVAs performed by an individual by completing his ninth (Table 3.2).

This fourth EVA of the Soyuz TM-17 mission, coupled with his five EVAs in 1990 during Soyuz TM-8, gave Serebrov a total of 27 hr 37 min outside Mir. Unexpectedly, however, the EVA of 22 October lasted only 38 min, allowing the two cosmonauts only to install a micro-meteoroid detection experiment and to briefly photograph portions of Mir's exterior. The EVA had been scheduled to last more than five hours. A fifth EVA on 29 October with a duration of 4 hr 12 min apparently allowed the team to complete all assigned tasks (References 166, 169-170).

The final two months of 1993 were spent engaged with routine activities and maintenance chores. The Progress M-20 spacecraft was undocked on 21 November, returning its Raduga capsule to Earth later that same day. Inside the capsule were the crystals grown under microgravity conditions for the US Boeing company. As the year drew to a close, final preparations for the start of the delayed Soyuz

TM-18 were underway. Meanwhile, Progress M-17 continued on its solo flight with a mean altitude of 294 km on New Year's Eve (References 171-174).

In other news from the Russian Mir space station program during 1993, four women began a six-month-long bed-rest experiment to study potential countermeasures to microgravity effects on the human body. Not too long after the test's conclusion in 1994, a female cosmonaut was scheduled to be launched to Mir for a record-setting mission of nearly six months, by far the longest space flight for any woman. Also in 1994, Sergei Krikalev was scheduled to be the first Russian cosmonaut to fly on board a US Space Shuttle in a prelude to later Mir-Space Shuttle docking missions. On a more somber note, Air Force Major and cosmonaut trainee Sergei Vozovikov drowned during survival training on 21 July 1993 (References 174-177).

TABLE 3.2 MIR SPACE STATION EVA RECORD, 1986-1994.

YEAR	DATE	EVA NO.	MISSION	COSMONAUTS	EVA DURATION	PRIMARY PURPOSE
1987	11-Apr	1	Soyuz TM-2	Romanenko/Laveykin	3 hr 40 min	Kvant 1 docking aid
	12-Jun	2	Soyuz TM-2	Romanenko/Laveykin	1 hr 53 min	Installation of solar panel
	16-Jun	3	Soyuz TM-2	Romanenko/Laveykin	3 hr 15 min	Installation of solar panel
1988	26-Feb	4	Soyuz TM-4	Titov, Manarov	4 hr 25 min	Replacement of solar panel; misc tasks
	30-Jun	5	Soyuz TM-4	Titov, Manarov	5 hr 10 min	Repair of Kvant 1 experiment
	20-Oct	6	Soyuz TM-4	Titov, Manarov	4 hr 12 min	Repair of Kvant 1 experiment
	9-Dec	7	Soyuz TM-7	Volkov/Chretien (Fr)	5 hr 57 min	Soviet-French construction experiment
1990	8-Jan	8	Soyuz TM-8	Viktorenko/Serebrov	2 hr 56 min	Installation of new star sensors
	11-Jan	9	Soyuz TM-8	Viktorenko/Serebrov	2 hr 54 min	Replacement of materials experiment
	26-Jan	10	Soyuz TM-8	Viktorenko/Serebrov	3 hr 02 min	Test of EVA suits and facilities
	1-Feb	11	Soyuz TM-8	Viktorenko/Serebrov	4 hr 59 min	Test of manned maneuvering unit
	5-Feb	12	Soyuz TM-8	Viktorenko/Serebrov	3 hr 45 min	Test of manned maneuvering unit
	17-Jul	13	Soyuz TM-9	Solovyev/Balandin	7 hr 16 min	Repair of Soyuz TM thermal blankets
	26-Jul	14	Soyuz TM-9	Solovyev/Balandin	3 hr 31 min	Repair of Soyuz TM thermal blankets & EVA hatch
	29-Oct	15	Soyuz TM-10	Manakov/Strekalov	2 hr 45 min	Repair of EVA hatch
1991	7-Jan	16	Soyuz TM-11	Afanasyev/Manarov	5 hr 18 min	Repair of EVA hatch
	23-Jan	17	Soyuz TM-11	Afanasyev/Manarov	5 hr 33 min	Installation of Strela crane
	26-Jan	18	Soyuz TM-11	Afanasyev/Manarov	6 hr 20 min	Installation of solar panel supports on Kvant 1
	25-Apr	19	Soyuz TM-11	Afanasyev/Manarov	3 hr 34 min	Inspection of Kvant 1 rendezvous system antenna
	24-Jun	20	Soyuz TM-12	Artsebarskiy/Krikalev	4 hr 58 min	Repair of Kvant 1 rendezvous system antenna
	28-Jun	21	Soyuz TM-12	Artsebarskiy/Krikalev	3 hr 24 min	Soviet-US experiment deployment; misc tasks
	15-Jul	22	Soyuz TM-12	Artsebarskiy/Krikalev	5 hr 56 min	Construction of Sofora girder
	19-Jul	23	Soyuz TM-12	Artsebarskiy/Krikalev	5 hr 28 min	Construction of Sofora girder
	23-Jul	24	Soyuz TM-12	Artsebarskiy/Krikalev	5 hr 34 min	Construction of Sofora girder
	27-Jul	25	Soyuz TM-12	Artsebarskiy/Krikalev	6 hr 49 min	Construction of Sofora girder
1992	20-Feb	26	Soyuz TM-12/13	Volkov/Krikalev	4 hr 12 min	Deployment of experiments; misc tasks
	8-Jul	27	Soyuz TM-14	Viktorenko/Kaleri	2 hr 03 min	Maintenance on Kvant 2 gyroscopes
	3-Sep	28	Soyuz TM-15	Solovyev/Avdeyev	3 hr 56 min	Installation of attitude control unit on Sofora
	7-Sep	29	Soyuz TM-15	Solovyev/Avdeyev	5 hr 08 min	Installation of attitude control unit on Sofora
	11-Sep	30	Soyuz TM-15	Solovyev/Avdeyev	5 hr 44 min	Installation of attitude control unit on Sofora
	15-Sep	31	Soyuz TM-15	Solovyev/Avdeyev	3 hr 33 min	Retrieval of experiment; misc tasks
1993	19-Apr	32	Soyuz TM-16	Manakov/Poleshchuk	5 hr 25 min	Preparation for Kvant 1 solar panel installation
	18-Jun	33	Soyuz TM-16	Manakov/Poleshchuk	4 hr 33 min	Preparation for Kvant 1 solar panel installation; misc tasks
	16-Sep	34	Soyuz TM-17	Tsibliyev/Serebrov	4 hr 18 min	Construction of Rapana girder
	20-Sep	35	Soyuz TM-17	Tsibliyev/Serebrov	3 hr 13 min	Construction of Rapana girder
	28-Sep	36	Soyuz TM-17	Tsibliyev/Serebrov	1 hr 52 min	Inspection of space station; misc tasks
	22-Oct	37	Soyuz TM-17	Tsibliyev/Serebrov	0 hr 38 min	Inspection of space station; misc tasks
	29-Oct	38	Soyuz TM-17	Tsibliyev/Serebrov	4 hr 12 min	Inspection of space station; misc tasks
1994	9-Sep	39	Soyuz TM-19	Malenchenko/Musabayev	5 hr 04 min	Inspection of space station; misc tasks
	13-Sep	40	Soyuz TM-19	Malenchenko/Musabayev	6 hr 01 min	Preparation for Kvant 1 solar panel installation

### 3.8.2 1994 Operations

Whereas the Salyut space stations had been regularly employed in setting new space endurance records to evaluate the long-term effects of microgravity on human physiology, Mir space station missions had typically reverted to standard 5-6 month flights after the year-long mission of the third expedition (Soyuz TM-4) during 1987-1988 (Figure 3.18). In part, this decision was based on considerable experience that the work efficiency of crew members began a noticeable decline after about six months in space. One exception to this policy was Sergei Krikalev's 10-month mission during 1991-1992 which was necessitated by other logistical constraints (Reference 178).

The Soyuz TM-18 mission, rescheduled for launch on 8 January 1994, was designed to at least partially alter this pragmatic trend to make further advances in space life sciences. Comprising the all-Russian 15th expedition to Mir were Commander Col. Viktor Afanasyev (a veteran of Soyuz TM-11), Flight Engineer Yuri Usachev (a rookie cosmonaut), and Cosmonaut

Researcher Dr. Valeri Polyakov (a veteran of Soyuz TM-6/4/7). Although Afanasyev and Usachov were due to be relieved after a normal six-month tour of duty, Polyakov, a medical doctor, was to remain on board for more than 14 months, establishing a new world record for continuous time in space. Moreover, with previous flight experience, Polyakov would have nearly 23 months cumulative space station habitation - another world record. Russian officials linked this new biomedical experiment with the eventual preparations for a manned mission to Mars (References 179-182).

Lift-off of Soyuz TM-18 from the Baikonur Cosmodrome occurred as planned on 8 January, and the spacecraft successfully docked at the vacant Kvant 1 aft port (Progress M-20 had departed on 21 November 1993) two days later. In a record turnaround, the Soyuz TM-17 crew departed Mir in their own spacecraft less than four days later on 14 January (Reference 183).

Prior to de-orbiting, Tsibliyev and Serebrov had one more task to perform: maneuver their

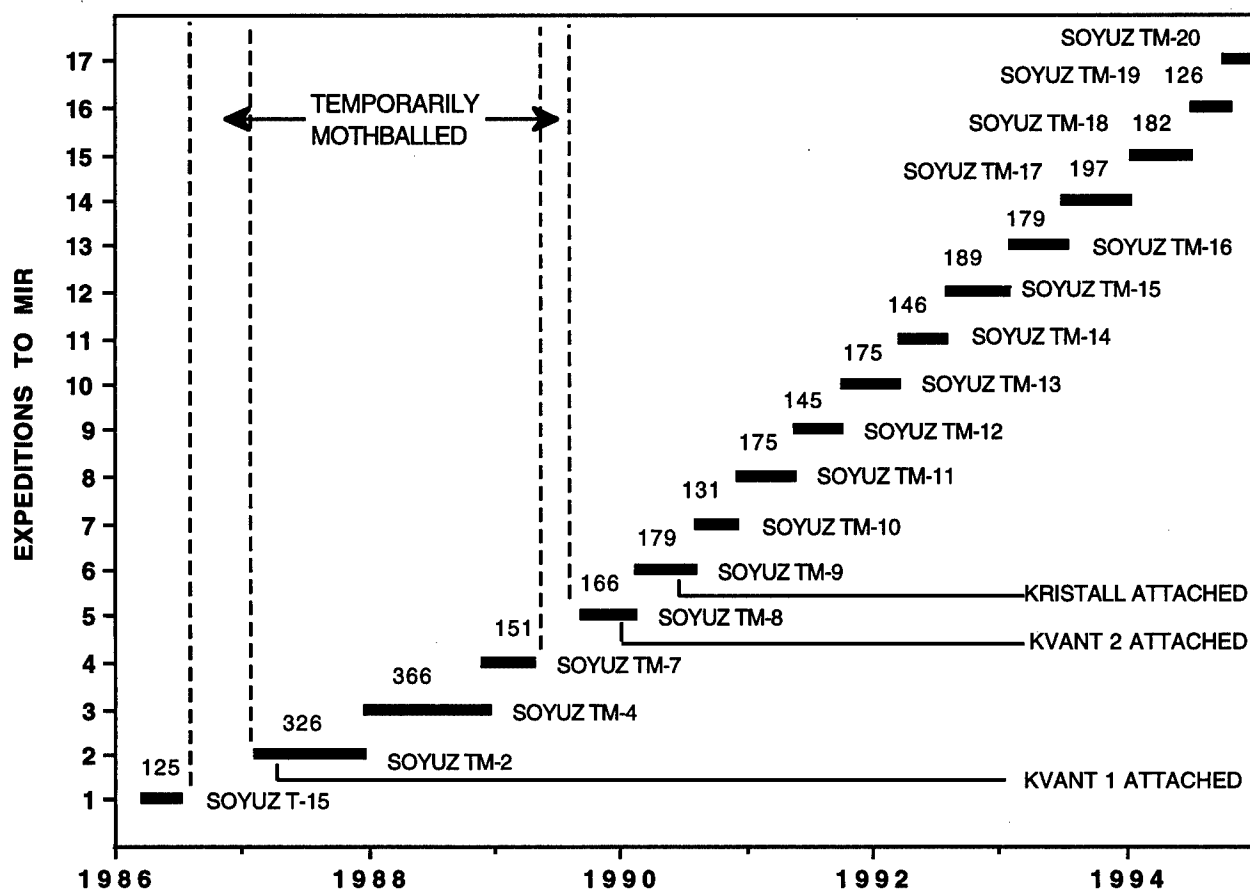


FIGURE 3.18 HISTORY OF MIR SPACE STATION EXPEDITIONS.

spacecraft from Mir's forward port to the Kristall forward APAS docking port and photograph a target to be used later during the Mir-Space Shuttle missions. At a distance of 45 m from Mir, Tsibliyev took manual control of Soyuz TM-17 and began his approach to Kristall while Serebrov prepared to take the requested photos from the vantage point of the ship's orbital module. Tsibliyev quickly realized that the spacecraft was not responding properly to his inputs and tried to avoid a collision with the complex. However, Soyuz TM-17 did bump into Kristall about 1.5 m behind the docking port, where fortunately, no external equipment was located. The impact was slight - the Soyuz TM-18 crew apparently did not feel it - but Mir's attitude control system was upset, and the station began to drift slowly. In turn, this reportedly broke the communications link with a Luch data relay satellite, aggravating an already tense situation in the TsUP (References 184-188).

The Soyuz TM-17 spacecraft was undamaged, and the crew was able to land safely less than four hours after the incident in a region 215 km west of Karaganda in Kazakhstan. A probe into the mishap found that a switch for the aft thruster was in standby mode rather than active. Reviews of the overall Soyuz TM-17 mission in January and February were positive but highlighted the substantial demand for maintenance on the aging space station. Despite a count of at least 240 micro-meteoroid impacts during the August, 1993, Perseid meteor shower, Mir was judged to be in good shape and capable of several more years of operations (References 189-190).

Before the next Progress M spacecraft was launched, the Soyuz TM-18 crew was instructed to move their ferry spacecraft from the Kvant 1 aft port to the Mir forward port. In the process they were also to inspect the area on Kristall where Soyuz TM-17 had struck. The Soyuz TM-18 fly-around was accomplished on 24 January, and only a few scratches were found on Kristall. The entire maneuver and inspection took less than two hours. Two days later Progress M-21 was launched, arriving at Mir on 30 January (Figure 3.19). During January officials also announced that the satellite tracking, telemetry, and control complex in Yevpatoriya, Ukraine, was once again supporting the Mir program after an absence of more than one year (References 191-195).

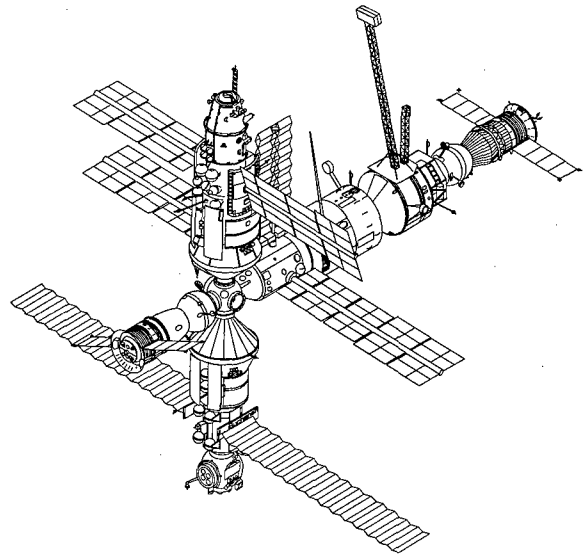


FIGURE 3.19 MIR SPACE STATION CONFIGURATION, JANUARY, 1994.

The next two months passed uneventfully. A minor celebration was held on 20 February, the eighth anniversary (Moscow time) of the launch of the Mir space station. On 3 March the flight of Progress M-17 finally came to an end with a destructive reentry into the atmosphere. Its propulsion system was tested one last time on 2 March after spending 11 months in space. Meanwhile, at the Baikonur Cosmodrome difficulties were being encountered, first with a fire on 7 March near Progress M-22, which was undergoing tests before mating to its booster, and then due to heavy snows (drifts up to six meters high) which delayed the launch of Progress M-22 by three days (References 196-197).

The new cargo spaceship eventually was launched on 22 March and guided along a normal 50-hour rendezvous profile. Its predecessor, Progress M-21 was undocked from the Mir complex on 23 March and then commanded to reenter the atmosphere the same day. Progress M-22 arrived at the space station on 24 March and docked with Kvant 1 without incident (Reference 198).

During the last week of March Afanasyev, Usachev, and Polyakov conducted a series of geophysical experiments, which reportedly included the injection of an electron beam along the geomagnetic field lines with the hope that the Swedish Freja satellite hundreds of kilometers away would detect it. April and May



were spent carrying out numerous scientific investigations in Earth observation, materials and life sciences, geophysics, and astrophysics. In mid-May, as the Progress M-22 mission was winding down, the automated vehicle used its propulsion system to push the orbital laboratory to its highest altitude of the 1993-1994 period (Figure 3.16). One week later on 23 May Progress M-22 was undocked and destroyed during reentry, following the launch of its successor the previous day. Progress M-23, the last logistics flight for the Soyuz TM-18 mission docked at the Kvant 1 aft port on 24 May, carrying the usual supplies as well as the first Raduga recovery capsule of the year (References 201-202).

The next manned expedition to Mir had been scheduled to lift-off on 20 June, but several problems, including acceptance of the Soyuz-U2 payload fairing, delayed the launch until 1 July. Soyuz TM-19 was a joint Russian-Kazakh endeavor with a scientific program continuing some of the investigations begun by Kazakh cosmonaut Aubakirov during Soyuz TM-13 in 1991. Commanding Soyuz TM-19 was Yuri Malenchenko accompanied by Flight Engineer Talgat Musabayev from Kazakhstan. Both men were making their first flights into space (References 203-209).

In accordance with the pattern established during the first half of 1994, Soyuz TM-19 was launched on 1 July, followed by the undocking of Progress M-23 on 2 July and the docking of Soyuz TM-19 on 3 July. This time, however, the departing Progress M spacecraft carried a Raduga capsule which was recovered 75 km northeast of Orsk, just north of the Kazakhstan border in the Russian Federation. For nearly six days the five cosmonauts worked together on board Mir until 9 July when Afanasyev and Usachev returned to Earth in Soyuz TM-18, leaving Polyakov with the new replacement crew (References 210-212).

Nearly seven weeks passed before the first and only Progress M flight of the Soyuz TM-19 mission commenced. Launch occurred on 25 August with a docking at the Mir forward port scheduled for 27 August. In what had become a routine procedure Progress M-24 approached the station nominally at a very slow relative velocity. However, at a distance of 150 m the automatic control system switched off and the docking attempt was aborted. This was the first such incident since a rash of initial docking failures during 1991-1992. Progress M-7 had

failed twice and Progress M-10 and M-13 had each failed once to dock with the space station, but in all cases the vehicles were ultimately successful in linking up with Mir (Reference 213-214).

A second attempt at docking was undertaken on 30 August. Again, the automatic approach was accomplished successfully until an on-board safety system terminated the procedure at a distance of 150 m. Although the safety systems prevented a serious collision between the cargo ship and the space station, Progress M-24 apparently bumped the station on this last try. Concern was also growing both on Mir and at the TsUP about the ability to continue the Soyuz TM-19 mission if Progress M-24 could not be saved. On 2 September a third try was planned, but this time Malenchenko would control Progress M-24 manually using the equipment which had been twice tested for this purpose in early 1993 (Progress M-15 and M-16). Malenchenko completed his assignment, linking the spacecraft with Mir in a textbook exercise (References 214-217).

One week after the successful docking, Malenchenko and Musabayev performed the first of two planned EVAs. The 9 September outing involved not only a series of programmed tasks, including the placement of new material samples for space exposure tests, but also a quick inspection of Mir where Progress M-24 had bumped it on 30 August. The latter survey found no significant damage. The two cosmonauts concluded their EVA after 5 hr 4 min. The second EVA on 13 September lasted 6 hr 1 min and concentrated on chores outside the Kvant 1 module, working on the solar array drives, inspecting the Sofora girder, and retrieving experiment samples from the Rapana truss (References 214, 218-221).

With the excitement of the Progress M-24 problems and the EVAs behind, the three Mir cosmonauts returned to their normal duties and prepared for the arrival of the next crew in early October. Soyuz TM-20 would mark the first Russian-ESA mission, code-named Euromir 94, and would last a full month. Consequently, the modest Mir space station was to be home for six cosmonauts for an extended period, testing both station resources and crew temperaments.

Soyuz TM-20 (Figure 3.20) was launched on 3 October (4 October, Moscow time, the 37th anniversary of the launching of Sputnik 1) with a crew of three: Commander Aleksandr

Viktorenko, Flight Engineer Yelena Kondakova, and Cosmonaut Researcher Ulf Merbold of ESA. Viktorenko was making his fourth flight in space, while rookie cosmonaut Konakova was seeking to set an endurance record for a woman in space. The German Merbold was on his third space flight, having served with the crews of STS-9 and STS-42 (References 222-224).

While Soyuz TM-20 was enroute to Mir, the troublesome Progress M-24 was released and allowed to be destroyed during reentry on 4 October. The Soyuz TM-20 spacecraft replaced it at the Mir forward port very early on 6 October, under the manual control of Viktorenko. An automatic docking had been planned, but, like the Progress M-24, Soyuz TM-20 veered from its intended course as it closed within 150 m. Viktorenko quickly assumed command and with Kondakova's assistance completed the docking only six minutes behind schedule (References 224-226).

The 30-day Euromir 94 mission began a little more than one year after four ESA

astronauts reported to the Yuri Gagarin Cosmonaut Training Center at Star City outside Moscow. Merbold was selected for the prime Soyuz TM-20 crew while Pedro Duque prepared as his backup. Meanwhile, Thomas Reiter of Germany and Christer Fuglesang began training for the even more ambitious, 135-day Euromir 95 mission. More than 30 life science, materials science, and general technology experiments were included in the busy Euromir 94 flight plan, ranging from the measurement of the thickness and tensile strength of skin tissue in space to investigating the behavior of composite materials during melting and solidification. Simultaneously, other members of the enlarged Mir crew were engaged in regular Russian experiments and space station maintenance tasks (References 224, 227-236).

The Euromir 94 program was largely successful but serious problems arose by the end of the first week. On the evening of 11 October an electrical power shortage caused a shutdown in the station's attitude control and navigation systems as the environmental control system was working at capacity to support the six cosmonauts. The former problem further aggravated the situation since Mir's solar arrays were no longer oriented to permit maximum power generation. Gradually the electrical power system was restored, in part by replacing several storage batteries, and by 18 October the crisis had passed. However, during much of this period the flight plan had to be revised, temporarily deferring experiments which consumed significant electrical power (References 237-243).

Another problem, which was not so amenable to a rapid solution, was a malfunctioning electric furnace which was to be used for materials science experiments. The furnace had actually broken prior to the start of Euromir 94, and replacement parts had been sent via Progress M-24. However, the device could not be fixed, causing ESA officials to request the experiments be completed by the cosmonauts remaining on board Mir after the conclusion of the Euromir 94 flight (References 244-245).

Mir mission managers, concerned about three successive automatic docking failures with Mir decided to add a new task to the Euromir 94 agenda. On 2 November Malenchenko, Musabayev, and Merbold entered the Soyuz TM-19 spacecraft, undocked from Kvant 1, and pulled away from the orbital

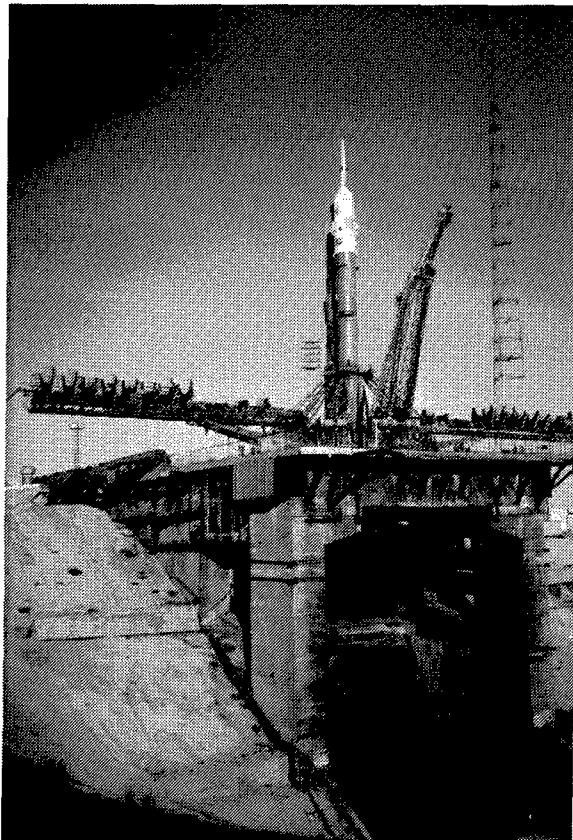


FIGURE 3.20 SOYUZ TM-20 PRIOR TO LAUNCH.

TABLE 3.3 MIR SPACE STATION LOGISTICAL SUMMARY, 1993-1994.

SPACECRAFT	DOCKING DATE	UNDocking DATE	SPACE STATION PORT	TOTAL STAY	COMMENTS
Soyuz TM-15	29 Jul 92	01 Feb 93	Mir, forward	187 days	Brought crew of Solovyev, Avdeyev, and Tognini; Returned with crew of Solovyev and Avdeyev
Progress M-15	29 Oct 92	04 Feb 93	Kvant 1, aft	97 days	Brought MAK-2 which was released 20 Nov 92 and the Banner experiment which was deployed 04 Feb 93
Soyuz TM-16	26 Jan 93	22 Jul 93	Kristall, forward	177 days	Brought crew of Manakov and Poleshchuk; Returned with crew of Manakov, Poleshchuk, and Haignere
Progress M-16	23 Feb 93 26 Mar 93	26 Mar 93 27 Mar 93	Kvant 1, aft	31 days	Undocked and redocked 26 Mar 93 to test remote control rendezvous and docking technique
Progress M-17	02 Apr 93	11 Aug 93	Kvant 1, aft	131 days	Conducted subsequent independent, long duration mission until 3 Mar 94 when natural decay was completed
Progress M-18	24 May 93	03 Jul 93	Mir, forward	40 days	First time two Progress vehicles docked at Mir simultaneously; Raduga capsule was returned 04 Jul 93
Soyuz TM-17	03 Jul 93	14 Jan 94	Mir, forward	195 days	Brought crew of Tsibilyev, Serebrov, and Haignere; Returned with crew of Tsibilyev and Serebrov
Progress M-19	12 Aug 93	12 Oct 93	Kvant 1, aft	62 days	Raduga capsule was returned 13 Oct 93
Progress M-20	13 Oct 93	21 Nov 93	Kvant 1, aft	38 days	Raduga capsule was returned 21 Nov 93
Soyuz TM-18	10 Jan 94 24 Jan 94	24 Jan 94 09 Jul 94	Kvant 1, aft Mir, forward	180 days	Brought crew of Afanasyev, Usachev, and Polyakov; Returned with crew of Afanasyev and Usachev
Progress M-21	30 Jan 94	23 Mar 94	Kvant 1, aft	52 days	
Progress M-22	24 Mar 94	23 May 94	Kvant 1, aft	60 days	
Progress M-23	24 May 94	02 Jul 94	Kvant 1, aft	39 days	Raduga capsule was returned 02 Jul 94
Soyuz TM-19	03 Jul 94 02 Nov 94	02 Nov 94 04 Nov 94	Kvant 1, aft Kvant 1, aft	124 days	Brought crew of Malenchenko and Musabayev; Returned with crew of Malenchenko, Musabayev, and Merbold; Undocked and redocked on 02 Nov 94 to test rendezvous system
Progress M-24	02 Sep 94	04 Oct 94	Mir, forward	32 days	Failed to dock on both 27 and 30 Aug 94
Soyuz TM-20	06 Oct 94	22 Mar 95	Mir, forward	167 days	Brought crew of Viktorenko, Kondakova, and Merbold; Returned with crew of Viktorenko, Kondakova, and Polyakov
Progress M-25	13 Nov 94	16 Feb 95	Kvant 1, aft	95 days	

complex. Although the three docking failures had been with the Mir forward port, Soyuz TM-19 was to verify that a system-level fault had not arisen in the Kurs rendezvous system. In the event a redocking was not possible, Soyuz TM-19 had already been loaded with the materials selected for return to Earth, and the crew could come home immediately. At a distance of 190 m the Kurs automatic mode was engaged, followed by a perfect approach and docking. The time from undocking to redocking was only 35 minutes (References 246-250).

The need for this additional test led to a final change in the Euromir 94 schedule. The return home of Malenchenko, Musabayev, and Merbold was delayed one day until 4 November. The trinational crew exited the Mir space station for the last time on the morning of 4 November and touched down northeast of Arkalyk in Kazakhstan less than four hours later. The landing was described as rough with strong winds causing the Soyuz TM-19 descent capsule to stray 9 km from its intended site and to bounce once before coming to rest. The cosmonauts, however, were unharmed and

were honored to be greeted by Nursultan Nazerbayev, President of Kazakhstan (References 246 and 251).

A more normal daily routine returned to Mir with the crew once again reduced to three cosmonauts: Viktorenko, Kondakova, and Polyakov. One week after the departure of the Soyuz TM-19 spacecraft, Progress M-25, the last mission to Mir in 1994, was launched. To the relief of both the Mir crew and the TsUP, the cargo ship docked without incident on 13 November with the Kvant 1 aft port in the automatic regime. The supplies on board would have to sustain the 17th Mir expedition until February, 1995, when the next Progress M vehicle was scheduled to arrive (References 252-253).

At the beginning of 1994 the long-term program for the Mir space station called for the oft-delayed launch of the large Spektr module on 27 November, followed by a docking with the complex in December. To prepare for its arrival, two of the Mir cosmonauts were to perform EVAs in November to transfer the Kristall solar arrays to the Kvant 1 module. All of these plans

were abandoned when integration and testing of Spektr fell behind schedule, ultimately postponing the launch until the Spring of 1995 (Reference 254).

The remainder of 1994 passed uneventfully on Mir, which completed its 50,000th revolution about the Earth on 17 November. By the end of the year Kondakova had shattered the endurance record for a woman in space, and Polyakov was rapidly closing in on the mark for male cosmonauts. With his previous flight experience, Polyakov had already set the record for the most time in space by a human.

During 1994 the cosmonaut corps was sharply reduced due to financial difficulties and the limited number of missions planned through the end of the decade. The three principal detachments remaining were representatives of the Russian Air Force (17), RKK Energiya (12), and the Institute of Biomedical Problems (2). Only two women were specifically identified as still active: Yelena Kondakova, who flew for the first time in 1994, and Nadezhda Kuzhelnaya, who was still waiting for her first assignment.

However, the interest in long-term flights by women appeared high as evidenced both by the mission of Kondakova and a new four-month (February-June) hypokinesia experiment with eight female volunteers. The Institute of Biomedical Problems also conducted a 135-day-long isolation experiment with three subjects in preparation for the Euromir 95 mission. Finally, in early 1994 the former USSR Unified State Aviation Search and Rescue Service, which is responsible for the recovery of cosmonauts during launch aborts or reentries, was reorganized as the Russian Federation Aerospace Search and Rescue Service, even as Kazakhstan was trying to restrict their training exercises and imposing new controls on actual cosmonaut recoveries in Kazakhstan (References 255-262).

### 3.8.3 Future Plans

The decision in 1993 by the Russian Federation to join the International Space Station program had profound effects on both the near-term and long-term plans and objec-

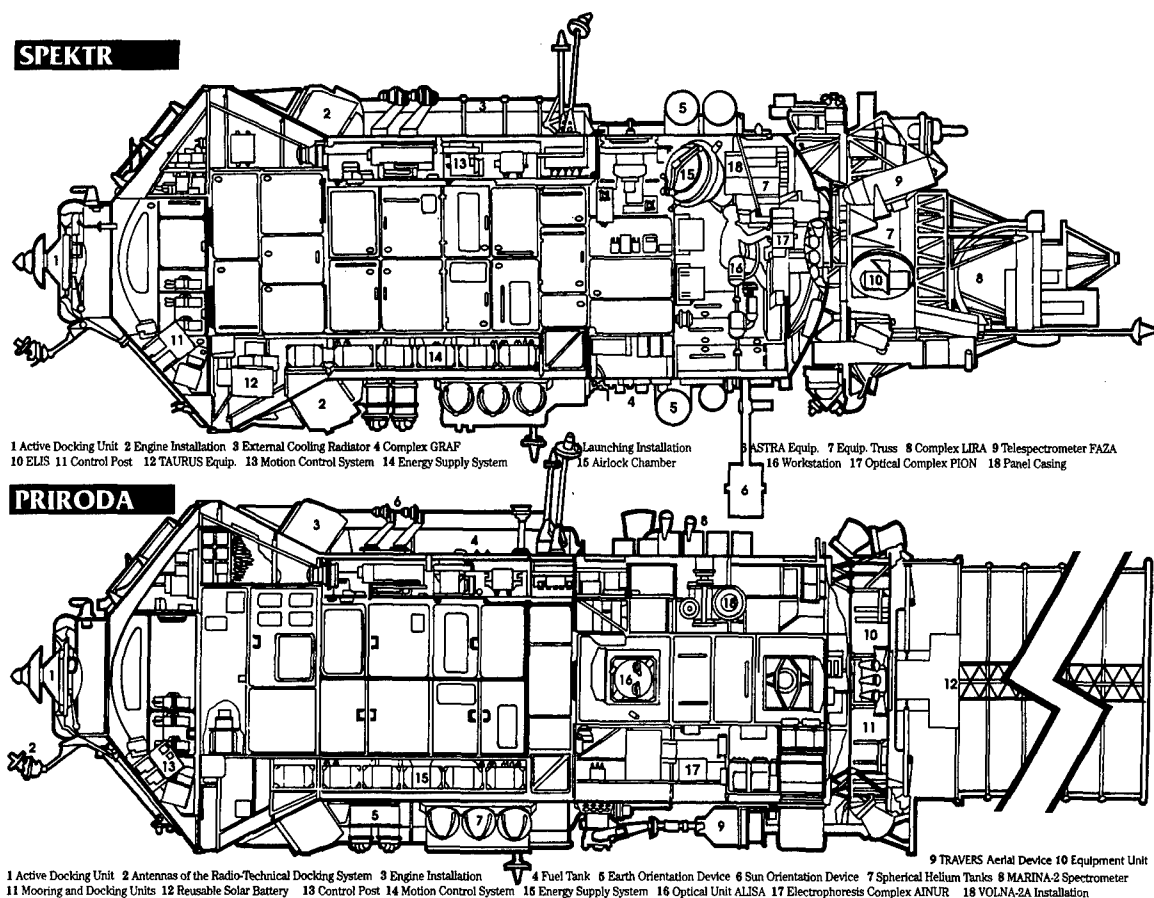


FIGURE 3.21 LAYOUT OF SPEKTR AND PRIRODA MODULES.

tives of the Russian man-in-space program. The first phase of the ISS program actually involves eight Mir-US Space Shuttle missions, of which seven call for dockings between the two massive objects. Following a Mir-Space Shuttle rendezvous and close fly-by in early 1995, the first two dockings were scheduled for the same year. The year 1995 was also to witness the dockings of the Spektr and Priroda modules (Figure 3.21) to the Mir complex, completing the assembly begun nearly 10 years earlier (Figure 3.22).

Three new expeditions to Mir were manifested for 1995, including a 3-month visit by the first American to visit Mir and the 4.5-month Euromir 95 mission. Late in the year a US Space Shuttle would deliver a new docking module which would be attached permanently to the Kristall module, in part, to provide additional clearance between the Space Shuttle and the Mir complex (Figures 3.23 and 3.24). US and Russian spacecraft engineers were also planning on taking advantage of this opportunity to deliver two more large solar arrays (one Russian and one American) to augment the Mir electrical power generation system.

Tentatively, 1996 and 1997 would mark the last years of Mir habitation. Two or three flights annually were envisioned, including new bilateral missions with the US and France. Requests by Japan and PRC for visits to Mir by their own astronauts were unlikely to be granted due to the increasingly packed schedule. With the launch of the first element of the ISS scheduled for November, 1997, followed by the first Russian-led manned mission the following Spring, the Mir space station was expected to be abandoned in late 1997 or 1998. However, the orbital laboratory might be allowed to continue on for a year or more to serve as a technology testbed. By the end of the decade,

the nearly 150-metric-ton space station was due to be deorbited over a broad ocean area to prevent any potential reentry hazards, as in the case of Skylab and Salyut 7.

Although plans for a Mir 2 space station had been abandoned, the principal components of this concept had been integrated into the late-1993 redesign of ISS. As indicated in Table 3.1, Russian-produced elements will account for approximately 150 metric tons of the 420 metric-ton complex as envisioned at assembly completion in 2002. Moreover, the Russian Federation will be responsible for unmanned logistical resupply missions and for the Assured Crew Return Vehicles (ACRVs). To support the former requirement, a Progress M2 spacecraft, which will be launched by a Ukrainian Zenit booster, is under development. The 13-m-long Progress M2 will have a cargo capacity of nearly five metric tons and will be capable of staying with ISS for up to six months. The ISS ACRVs will be derived from the current Soyuz TM spacecraft.

### **3.9 UKRAINE**

Although 15 Ukrainian-born cosmonauts have flown in space between 1962 and 1994, the new National Space Agency of Ukraine, unlike Kazakhstan, has not sponsored national manned space missions. To date all Ukrainian cosmonauts have represented either the former Soviet Union or the Russian Ministry of Defense. Due primarily to fiscal constraints this situation will likely remain unchanged through the end of the decade. However, Ukraine will serve a vital commercial role in the ISS program as the vendor of the Zenit-2 launch vehicle which will carry most of the Russian permanent elements as well as the Progress M2 logistics spacecraft.

# **MIR** **SPACE STATION** **COMPLEX**

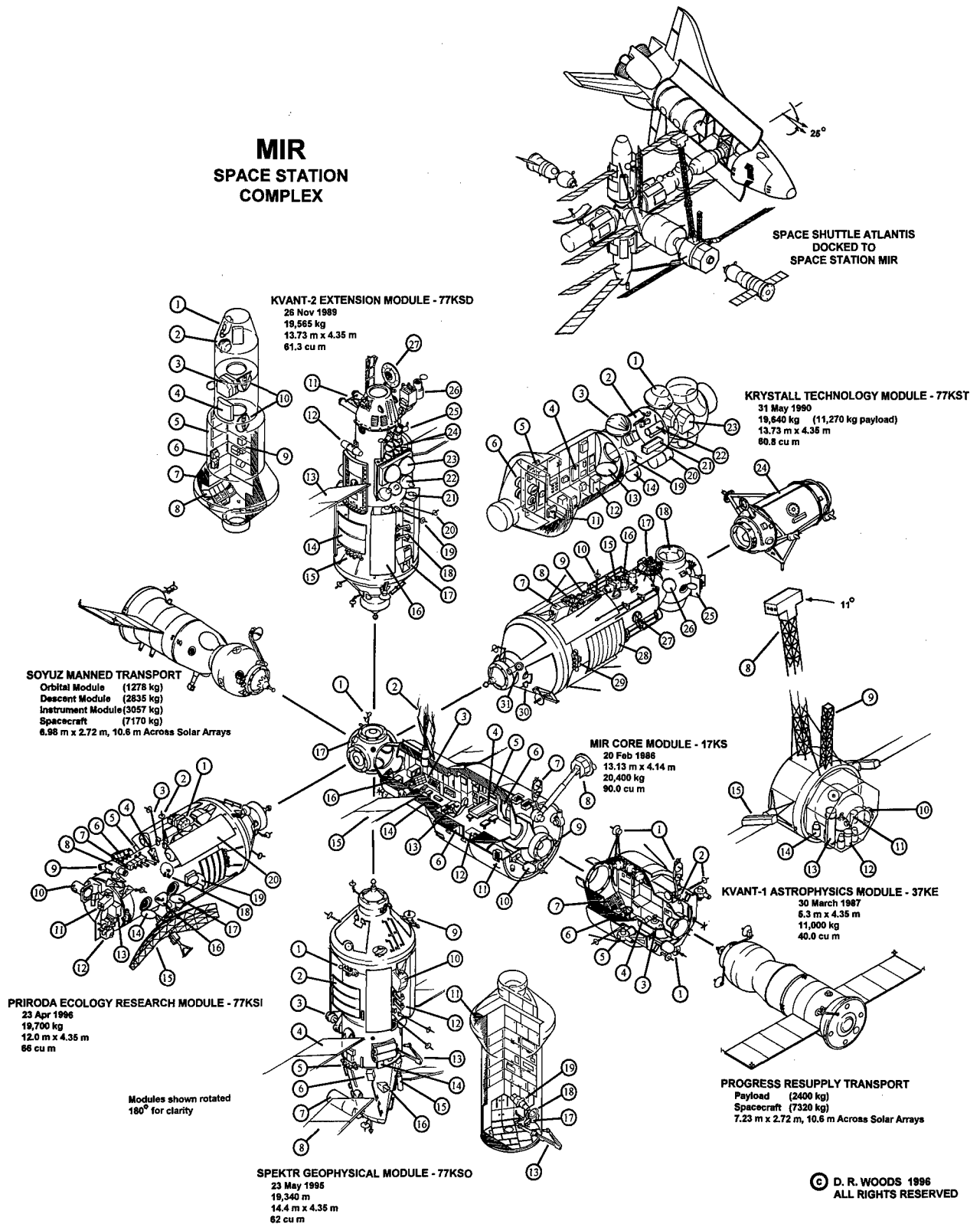


FIGURE 3.22 COMPLETED MIR SPACE STATION.

### MIR CORE MODULE - 17KS

- |  |   |   |
|--|---|---|
| 1. Kurs Rendezvous Antenna               | 7. Igla Rendezvous Antenna                  | 12. Exercise Treadmill                      |
| 2. Auxiliary Solar Array (340 kg) 10.6 m | 8. SDRN Luch Satellite Antenna (11/14 GHz)  | 13. Veloergometer Bicycle Exerciser         |
| 3. Module Control Consoles               | 9. Maneuvering Thruster (2) 300 kgf/ea      | 14. 50 Liter Refrigerator                   |
| 4. Meal And Work Table                   | 10. Igla Rendezvous Antenna                 | 15. Nine Panel Solar Array (2) 29.73 m Span |
| 5. Cooking Elements                      | 11. Attitude Control Thrusters - 6 Clusters | 16. Salyut-5B/Argon-16B Control Computers   |
| 6. Personal Sleeping Compartment (2)     | 32 Thrusters (total) 14 kgf/ea              | 17. Lyappa Module Rotation Socket           |

### KVANT-1 ASTROPHYSICS MODULE - 37KE

- |  |  |  |
|--|--|--|
| 1. Igla Rendezvous Antenna                       | 8. Sofora Truss (14.5 x 1.5 x 1.5 m) With VDU Roll Control Thruster Complex (700 kg) | 13. TTM Coded Mask Telescope 2-30 kev 60 kg  |
| 2. Kurs Rendezvous Antenna                       | 9. Rapana Truss (26 kg) 5 m  | 14. Pulsar X-Ray Spectrometer Telescope (5) 20-800 kev                               |
| 3. Sluice Airlock Chamber on Glazar UV Telescope | 10. Phoswich X-Ray Spectrometer 15-200 kev   | 15. MSB-2 And MSB-4 Extendable Solar Arrays (2) From Krystall (250 kg/ea) 7.5 m Span |
| 4. MKF-6 Multi Spectral Camera                   | 11. GSPC - Gas Scintillation Proportional Counter Spectrometer 2-100 kev             |  |
| 5. Attitude Control Star Sensor (2) 80 kg/ea     | 12. Sirene-2 High Pressure Gas Scintillation Proportional Spectrometer 2-100 kev     |  |
| 6. Visual Measurement And Photographic Device    |  |  |
| 7. Module Control Consoles                       |  |  |

### KVANT-2 EXTENSION MODULE - 77KSD

- |   |   |  |
|---|---|--|
| 1. Orian-DMA EVA Space Suit With 50 m Umbilical   | 13. VEP-3 And VEP-4 Solar Arrays 24.13 m Span   | 22. Gyrodyne Control Moment Units (3) 490 kg   |
| 2. KAP-350 Topography Photo Camera                | 14. Thermal Radiator (2)  | 23. Rodnik Water Supply (2) 300 liter / 420 kg ea  |
| 3. MKF-6MA Multi-Spectral Camera (6 Bands)        | 15. Attitude Control Thrusters (4 Clusters) - 5 Approach Thrusters (40 kgf/ea) - 4 Stabilization Thrusters (1.5 kgf/ea) | 24. EVA Repressurization Air Supply (4) 28 kg  |
| 4. Control Panel                                  | 16. Thermal Shield Over Propellant Tank   | 25. Attitude Control Star Sensors (3)  |
| 5. NiCd Electrical Storage Batteries              | 17. Course Correction And Rendezvous Thruster (2) 415 kgf/ea  | 26. ASPG-M Gimballed Platform (110 kg) - MKS-M2 Optical Spectrometer - ITS-7D IR Spectrometer - ARIZ X-Ray Sensor - Gamma-2 Video Spectropolarimeter |
| 6. Volna-2 Capillary Action Fuel Development Unit | 18. Attitude Control Star Sensors (2)   | 27. EVA Hatch (1 m dia)  |
| 7. Liquid And Waste Management System             | 19. Kub Kontur Command Antenna  |  |
| 8. Module Control Consoles                        | 20. Kurs Rendezvous Antenna   |  |
| 9. Incubator-2 Biotechnical Complex               | 21. Propellant Tank (4) 600 kg  |  |
| 10. Section Separation Hatch                      |   |  |
| 11. Ryabina-2 Celestial Radiation Source Detector |   |  |
| 12. Phasa AFM-2 Near Earth Atmosphere Telescope   |   |  |

### KRYSTALL TECHNOLOGY MODULE - 77KST

- |  |   |  |
|--|---|--|
| 1. Marina-2 Thermal Cover  | 12. Svet Botanical Research Complex                             | 24. Space Shuttle Docking Module - 316GK 4085 kg 4.75 x 2.22 m |
| 2. TSB Thermostat  | 13. Section Separation Hatch                                    | 25. Thruster Plume Shield                                      |
| 3. Glazar-2 Housing  | 14. Rodnik Water Supply (2)                                     | 26. Granat Spectrometer  |
| 4. Krater-B Electric Furnace - Gallium Arsenide                    | 15. Glazar-2 UV Telescope                                       | 27. Solar Array Mount (Arrays Transferred To Kvant-1)          |
| 5. Optizon-1 Electric Furnace - Silicon                            | 16. Ksenia  | 28. Thermal Radiators (2)                                      |
| 6. Electric Crucibleless Furnaces - Metal Melt - Zona-02 - Zona-03 | 17. Marina Spectrometer   | 29. Attitude Control Thrusters                                 |
| 7. Course Correction And Rendezvous Thruster (2) 415 kgf/ea        | 18. APAS-89 Docking Port  | 30. Solar Attitude Sensor (4 Sets)                             |
| 8. Earth Horizon Attitude Control IR Sensors (2)                   | 19. TUB Thermostat  |  |
| 9. Helium Pressurization Tanks (6)                                 | 20. B16M (2)  |  |
| 10. Kurs Rendezvous Antenna  | 21. Ainur Electrophoretic Complex                               |  |
| 11. Maria-2 Spectrometer   | 22. ChSK-1 Crystallizer   |  |
|  | 23. Priroda-5 High Resolution Cameras (2) - SA-20M-I - SA-20-11 |  |

### SPEKTR GEOPHYSICAL MODULE - 77KSO

- |   |  |                                   |
|---|--|-----------------------------------|
| 1. Attitude Control Thrusters               | 8. Eight Segment Auxiliary Solar Array (2)                     | 13. Pelican Manipulator Arm       |
| 2. Thermal Radiators (2)                    | 9. Kurs Rendezvous Antenna                                     | 14. Komza Interstellar Gas Sensor |
| 3. Astra-2 Atmospheric Trace Element Sensor | 10. Course Correction And Rendezvous Thruster (2) 415 kgf/ea   | 15. Phasa Telespectrometer        |
| 4. Seven Segment Primary Solar Array (2)    | 11. Taurus / Grif-1 X-Ray / Gamma Ray Induced Radiation Sensor | 16. Phoenix IR Spectrometer       |
| 5. Attitude Control Thrusters               | 12. Attitude Control Solar Sensors (4 Sets)                    | 17. Sluice Airlock Chamber        |
| 6. Ryabina-4P Cosmic Radiation Sensor       |  | 18. Astra View Port               |
| 7. Miras Atmospheric Spectrometer           |  | 19. Priroda Cameras (2)           |

### PRIRODA INTERNATIONAL ECOLOGY RESEARCH MODULE - 77KSI

- |  |   |  |
|--|---|--|
| 1. MOM-02P Earth Imager  | 9. DK-35 Photometer                               | 16. Travers Synthetic Aperture Mapping Radar       |
| 2. KUB Kontur Command Antenna  | 10. DOPI  | 17. Alisa Aerosol Lidar Ocean Altimeter            |
| 3. Kurs Rendezvous Antenna   | 11. ISTOK-1 Microwave Radiometer                  | 18. IKAR-D: RP-225 Microwave Radiometer (Scanning) |
| 4. IKAR-N: RP-600 Microwave Radiometer (Fixed)                       | 12. MSU-5K Multi Spectral Scanner                 | 19. Delta-ZP Multi Channel Scanning Radiometer     |
| 5. Canopus Equipment   | 13. Greben Ocean Radar Altimeter                  | 20. Meteor/Thermal Shield Over Propellant Tank (4) |
| 6. Marina-2 Radiometer   | 14. MOZ-Obzor Multi Zonal Spectrometer            |  |
| 7. IKAR-D: R-30, R-80, R-135, R-225P Microwave Radiometer (Scanning) | 15. IKAR-D: R-400 Microwave Radiometer (Scanning) |  |
| 8. Ozone-M Spectrometer  |   |  |



FIGURE 3.23 PLANNED INITIAL DOCKING OF MIR AND US SPACE SHUTTLE.



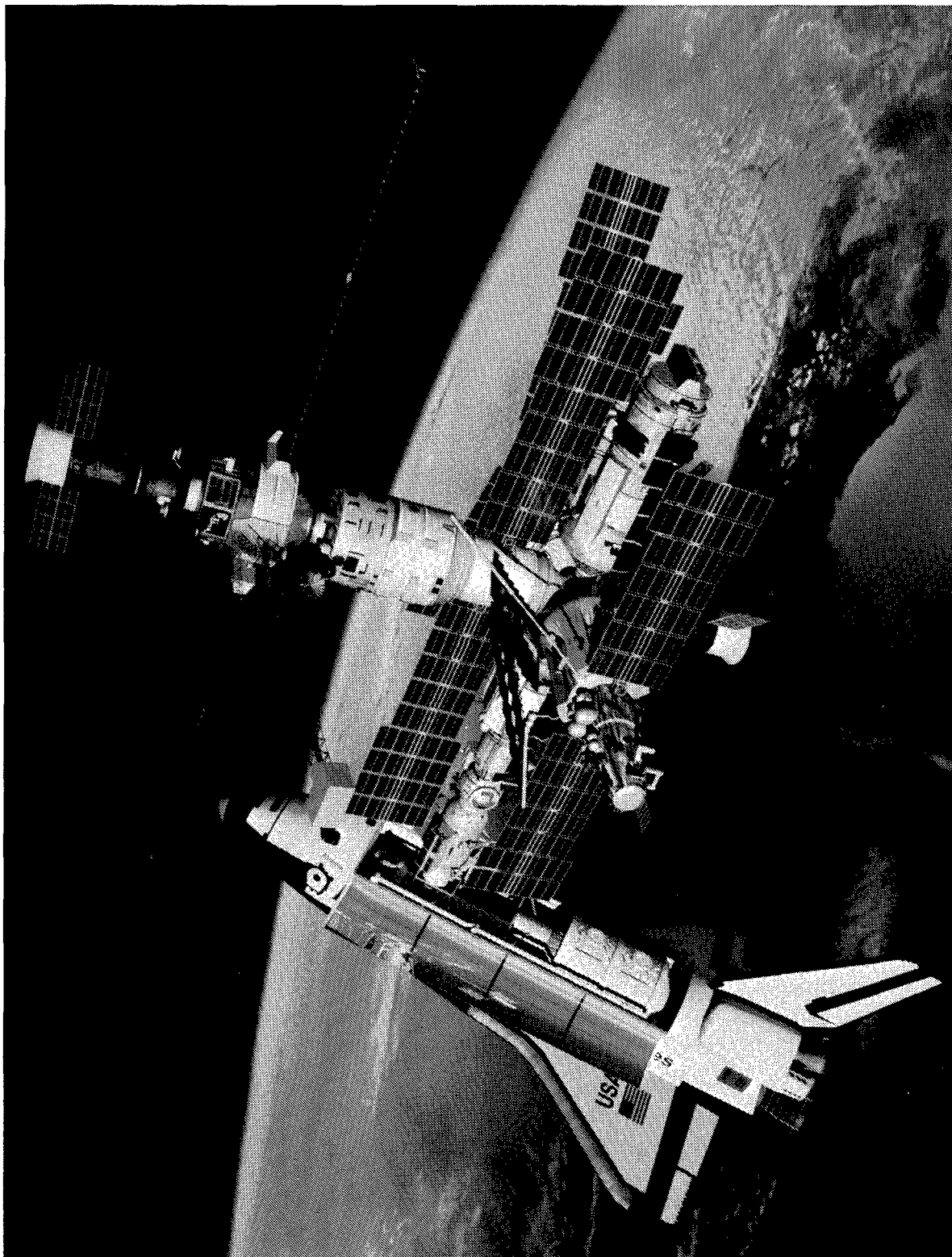


FIGURE 3.24 MIR-US SPACE SHUTTLE DOCKING WITH SPECIAL DOCKING MODULE.

### References - Section 3

1. A. Lawler, "Details of Redesign Team Findings Sent to White House", Space News, 14-20 June 1993, p. 20.
2. P. Mann and J.R. Asker, "Clinton Backs Smaller, Cheaper Space Station", Aviation Week and Space Technology, 21 June 1993, pp. 20-21.
3. D. Payson, Rossiyskiye Vesti, 1 June 1993, p. 8.
4. Russian-American Cooperation in Manned Space Stations, Working Group report, August, 1993.
5. A. Lawler, "White House Considers Mir Option", Space News, 23-29 August 1993, pp. 1, 20.
6. Alpha Station Program Implementation Plan, NASA, September, 1993.
7. Space Station Transition Plan, NASA, 7 September 1993.
8. P. Mann, "U.S., Russia Draft Historic Space Pact", Aviation Week and Space Technology, 6 September 1993, pp. 22-23.
9. J.R. Asker, "NASA Details New Station Plans", Aviation Week and Space Technology, 13 September 1993, pp. 20-21.
10. A. Zak, Nezavisimaya Gazeta, 29 September 1993, p. 6.
11. R.H. Kohrs and E.K. Huckins, "An Update on the Development of the Space Station", Paper IAF-93-T.1.495, 44th Congress of the International Astronautical Federation, October 1993.
12. A.F. Gearing, et al, "U.S./Russian Cooperation on Space Station: The NASA/NPO Energia Studies Contract", Paper IAF-93-T.6.532, 44th Congress of the International Astronautical Federation, October 1993.
13. Alpha Station Addendum to Program Implementation Plan, NASA, 1 November 1993.
14. Trud, 17 November 1993, p. 1.
15. Letter Contract NAS15-10110 between NASA and the Russian Space Agency for Supplies and Services Relating to Mir-1 and the International Space Station: Phase One and Selected Phase Two Activities, signed December 1993.
16. International Space Station Alpha Reference Guide, Boeing Missiles & Space Division for NASA, CSA, ESA, ASI, NASDA, and RSA, 30 November 1994.
17. K. Lantratov, International Space Station Alpha, Novosti Kosmonavtiki special edition, July 1995.
18. Spacelab Data Book, ESA BR-14, ESA, September 1983.
19. D.J. Shapland and F. Rositto, "European Manned Space Programmes", Spaceflight, February 1994, pp. 54-56. See Section 3.8 for details on the Euromir 94 and Euromir 95 missions.

20. All About the European Space Agency, May 1995, p. 7.
21. Annual Report '94, ESA, 1995, pp. 62-65.
22. P.B. de Selding, "Europeans Consider Shrinking Their Station Laboratory", Space News, 19-25 July 1993, p. 22.
23. P.B. de Selding, "Europe Faces Station Choice", Space News, 26 September - 2 October 1994, p. 1.
24. P. Langereux, "Un Module Habite Europeen Reduit De Moitie", Air & Cosmos, 4 November 1994, p. 37.
25. Columbus. A User's Introduction, ESA BR-62, ESA, September, 1989.
26. J. M. Lenorovitz, "European Industry Submits Proposal For Space Station Design/Development", Aviation Week and Space Technology, 16 October 1989, p. 22.
27. Columbus. Europe Bound for the 21st Century, ESA, 1987.
28. Annual Report '93, ESA, 1994, pp. 59-61.
29. M. Senechal, "Demonstrating Reentry", Space, May-June 1995, pp. 18-20.
30. C. Lardier, "La Capsule ARD Sera Livree En Janvier 1996", Air & Cosmos, 9 June 1995, p. 78.
31. P.B. de Selding, "Fillon Backs Crew Capsule", Space News, 3-9 July 1995, pp. 3, 20.
32. P. Langereux, "Rendezvous En Decembre Sur Les Projects De L'ESA", Air & Cosmos, October 1993, p. 42.
33. P.B. de Selding, "ESA Board Approves Capsule Research", Space News, 6-12 December 1993, pp. 1, 20.
34. "Assured Crew Return Vehicle", Spaceflight, October 1993, pp. 328-329.
35. "ESA Sets Reentry Test", Aviation Week and Space Technology, 12 September 1994, p. 28.
36. P.B. de Selding, "ESA To Develop Recoverable Orbital Capsule", Space News, 3-9 October 1994, p. 6.
37. P. Moller, et al, "EVA Suit 2000", Paper IAF/IAA-93-6.4.164, 44th Congress of the International Astronautical Federation, October 1993.
38. "EVA Suit", Spaceflight, October 1993, pp. 330-331.
39. "ESA's Space Infrastructure Plans", Spaceflight, October 1993, pp. 330-331.
40. "ESA Seeks Space Cooperation with Russia", Spaceflight, October 1993, pp. 326-327.
41. ITAR-TASS News Agency, 5 October 1994.

42. P.B. de Selding, "ESA, Russians Discussing Joint Station Projects", Space News, 10 October 1994, pp. 1, 20.
43. "Europe OKs Robot Arm, Defers Other Decisions", Space News, 19-25 September 1994, p. 2.
44. P.B. de Selding, "Europe Drops Shuttle Effort", Space News, 27 September - 3 October 1993, pp. 1, 28.
45. C. Lardier, "J-F Clervoy Cinquieme Francois De L'Espace", Air & Cosmos, 11 November 1994, pp. 36-37.
46. C. Lardier, "L'Astronaute Jean-Francois Clervoy Pourrait Revoler Dans 2 ou 3 Ans", Air & Cosmos, 23 December 1994, p. 61.
47. A. Ducrocq, "Pour Que La Station Ne Soit Pas Pernicieuse", Air & Cosmos, 9 December 1994, p. 37.
48. J.-L. Chretien, "Vols D'Astronautes Francais en 1996-97", Air & Cosmos, 6 January 1995, p. 60.
49. "La Mission Cassiopee Passe De 14 a 16 Jours", Air & Cosmos, 13 January 1995, p. 39.
50. Experiments in Space. The Second German Spacelab Mission D-2, DLR, 1992.
51. M.H. Keller and P.R. Sahm, "The German Spacelab Mission D2: A Scientific and Technological Challenge", Earth Space Review, Vol. 3, No. 1, 1994, pp. 11-21.
52. R. Shuiling, "Columbia Reaches '100th Day in Space': Shuttle Program Clocks Up 'One Year in Space'", Spaceflight, July 1993, pp. 232-236.
53. J.M. Lenorovitz, "Politics May Force German Space Station Cuts", Aviation Week and Space Technology, 3 May 1993, p. 58.
54. J.T. McKenna, "Mission Tests Techniques for Space Station Work", Aviation Week and Space Technology, 18 July 1994, pp. 82-83.
55. Kyodo News Service, 11 October 1994.
56. NASDA. National Space Development Agency of Japan, NASDA, 1994, pp. 11-12, 25-26.
57. NASDA Report, NASDA, No. 24, Spring 1994, pp. 12-13 and No. 36, June 1995, pp. 5-6.
58. N.W. Davis, "Japan Prepares for Crewed Space Activities", Aerospace America, September 1994, pp. 6-8.
59. "Japanese To Announce JEM Experiment Selections", Space News, 19-25 July 1995, p. 14.
60. "Japan Begins \$2.5-Billion Effort To Develop Freedom Station Module", Aviation Week and Space Technology, 20 August 1990, pp. 79, 82.
61. L. David, "Japan's Space Station Contribution Enters Critical Stage", Space News, 24-30 September 1990, pp. 10, 12.

62. K. P. Dawson, "Japan's Station Program Nears Start of Key Design Review", Space News, 25 November-1 December 1991, p. 18.
63. K. P. Dawson, "Japan Begins Building Station Module Model", Space News, 16-22 November 1992, p. 23.
64. E. Sekigawa, "Japan Committed to Space Station", Aviation Week and Space Technology, 5 April 1993, p. 59.
65. "Shuttle to Carry Chinese Astronaut", Aviation Week and Space Technology, 9 April 1984, p. 16.
66. Orlando Sentinel Star, Orlando, 21 January 1979, p. 4-D.
67. "China Beginning Manned Space Effort", Aviation Week and Space Technology, 28 May 1979, pp. 26-27.
68. L. Mathews, "China Trains Its First Astronauts", Los Angeles Times, 13 January 1980, p. 18.
69. "Astronaut Candidates Training in China for Future Missions", Aviation Week and Space Technology, 4 February 1980, p. 57.
70. "Chinese Astronauts Train in Simulators", Aviation Week and Space Technology, 26 January 1981, pp. 62-63.
71. "Chinese Space Station, As 'Head of a Dragon', Would Boost Economy", Aerospace Daily, 10 December 1985, pp. 198-199.
72. Liu Ji-yuan and Min Gui-rong, "The Progress of China's Astronautics", U.S. Space Foundation Symposium, Colorado Springs, 22 January 1987.
73. "China Plans Space Station/Cargo Vehicle", Defense Daily, 11 June 1987, p. 239.
74. C. Covault, "China Developing Technology for Future Manned Space Flight", Aviation Week and Space Technology, 29 June 1987, pp. 22-23.
75. "Chinese Studies on Space Station Begin", Defense Daily, 28 September 1987, p. 159.
76. Y. Chen, "China's Space Policy - A Historical Review", Space Policy, May 1991, pp. 116-128.
77. "China Eyes Manned Space Capsule", Aviation Week and Space Technology, 10 December 1990, p. 24.
78. Zhongguo Tongxun She News Agency, 31 October 1992.
79. A. Lawler, "Chinese Propose Building Capsule To Orbit Astronauts", Space News, 31 January - 6 February 1994, pp. 1, 20.
80. A. Lawler and B. Opall, "Chinese Consider Buying Russian Soyuz Technology", Space News, 11-17 July 1994, pp. 1, 20.
81. Interfax News Agency, 3 March 1995.

82. ITAR-TASS News Agency, 14 March 1995.
83. "PRC Evaluating Possible Participation in Space Station", Aviation Week and Space Technology, 26 May 1986, pp. 21-23.
84. "Chinese Officials Probe Potential Station Role", Space News, 31 October - 6 November 1994, p. 2.
85. Z. Huang, "Fully Reusable Launch Vehicle with Airbreathing Booster", IAF-83-376, 34th Congress of the International Astronautical Federation, 10-15 October 1983.
86. The "Soyuz" Transportation Spacecraft, brochure issued by Energiya NPO, 1991 and later editions.
87. V. A. Pivnyuk, Space Station Handbook, Matson Press, 1992.
88. Yu. Semenov and V. Timchenko, Pravda, 5 August 1987, p. 3.
89. W.R. Matson, ed., Cosmonautics. A Colorful History, Cosmos Books, 1994.
90. S.P. Korolev Space Corporation Energia, RKK Energiya, 1994.
91. Progress M, technical specification sheet distributed by Energiya NPO, 1991.
92. Recoverable Ballistic Capsule, technical specification sheet distributed by Energiya NPO, 1990.
93. Krasnaya Zvezda, 23 August 1989, p. 3.
94. Gudok, 26 August 1989, p. 4.
95. Sovetskaya Rossiya, 26 August 1989, p. 1.
96. I. Pochkayev, et al, Aviatsiya I Kosmonavtika, September 1987, pp. 44-45.
97. J. K. Beatty, "The High-Flying Kvant Module", Sky and Telescope, December 1987, pp. 599-601.
98. "77 KSD, Extension Module", technical specifications brochure distributed by Khrunichev Machine Building Plant, 1989.
99. M. M. Lemelev, Zemlya I Vselennaya, May-June 1990, pp. 3-11.
100. G. Glabay, Aviatsiya I Kosmonavtika, February 1991, pp. 46-47.
101. G. Lomanov, Sotsialisticheskaya Industriya, 2 August 1989, p. 4.
102. Krasnaya Zvezda, 2 December 1989, p. 5.
103. Pravda, 27 November 1989, p. 1.

104. "77 KST, Docking Support Module", technical specifications brochure distributed by Khrunichev Machine Building Plant, 1989.
105. G. Sergeyev, Aviatsiya I Kosmonavtika, March 1991, pp. 46-47.
106. Krasnaya Zvezda, 4 April 1990, p. 3.
107. Pravda, 1 June 1990, p. 3.
108. For additional historical and operation details of the Soviet/Russian space station programs see,  
  
User's Guide. Permanent Orbital Modular Complex "Mir", undated.  
  
A Russian Space Station: The Mir Complex, TD501, Mission Operations Directorate, NASA Johnson Space Center, 10 February 1994.  
  
D.S. Portree, Mir Hardware Heritage, RP 1357, NASA Johnson Space Center, March 1995.
109. ITAR-TASS News Agency, 11 December 1992.
110. ITAR-TASS News Agency, 12, 15, 19, 22, 23, and 24 January 1993.
111. S. Leskov, Izvestiya, 11 January 1993, p. 2.
112. Novosti Kosmonavtiki, 1-17 January 1993, pp. 5-7.
113. Novosti Kosmonavtiki, 18-31 January 1993, pp. 5-10.
114. V. Baberdin, Krasnaya Zvezda, 27 January 1993, p. 1.
115. ITAR-TASS News Agency, 25 and 26 January 1993.
116. Novosti Kosmonavtiki, 1-14 February 1993, pp. 5-12.
117. ITAR-TASS News Agency, 1 February 1993.
118. A. Konakov, Rossiyskiye Vesti, 13 February 1993, p. 5.
119. B. Olesyuk, Gudok, 20 February 1993, p. 3.
120. ITAR-TASS News Agency, 3 February 1993.
121. ITAR-TASS News Agency, 4 February 1993.
122. V. Lagovskiy, Rabochaya Tribuna, 5 February 1993, p. 8.
123. S. Leskov, Izvestiya, 10 February 1993, p. 6.
124. Narodnaya Armiya, 22 January 1993, p. 4.

125. Space Experiment Znamya, technical materials, NPO Energiya and Space Regatta Consortium, 1993.
126. "Space Experiment Znamya", Aviation & Space News, Vol. 1, No. 1, 1993, p. 2.
127. Y. Meshkov, Nezavisimaya Gazeta, 9 January 1992.
128. M. Rebrov, Krasnaya Zvezda, 13 December 1991, p. 4.
129. Kosmicheskiye Issledovaniya, July-October 1994, pp. 186-193 and 213-216.
130. N. Kidger, "Mir Mission Report", Spaceflight, May 1993, pp. 173-175.
131. ITAR-TASS News Agency, 5-7 February 1993.
132. ITAR-TASS News Agency, 9, 12, and 24 February 1993 and 2, 5, 9, 12, 19, and 23 March 1993.
133. ITAR-TASS News Agency, 26 and 27 March 1993.
134. ITAR-TASS News Agency, 19 April 1993.
135. V. Kiernan, "Mir Equipment Breaks, Delays Next Two Spacewalks", Space News, 26 April - 2 May 1993, p. 11.
136. Novosti Kosmonavtiki, 12-25 April 1995, pp. 6-9.
137. Novosti Kosmonavtiki, 10-23 May 1995, pp. 5-8 and 24 May - 6 June 1993, pp. 5-9.
138. ITAR-TASS News Agency, 13, 22, and 24 May 1993.
139. "March Launch of Progress To Carry Sculpture to Mir", Space News, 8-14 February 1993, p. 12.
140. A. Woods, "Art in Space: The Spaceflight of the Cosmic Dancer Sculpture", Earth Space Review, Vol. 3, No. 2, 1994, pp. 9-14.
141. ITAR-TASS News Agency, 18, 19, and 22 June 1993.
142. Novosti Kosmonavtiki, 7-20 June 1993, pp. 5-11.
143. Novosti Kosmonavtiki, 21 June - 4 July 1993, pp. 8-23.
144. M. Rebrov, Krasnaya Zvezda, 26 June 1993, p. 3, and 1 July 1993, p. 1.
145. V. Kamyshev, Gudok, 2 July 1993, p. 4.
146. P.B. de Selding, "French Astronaut Prepares for July Trip to Russia's Mir Space Station", Space News, 15-21 March 1993, p. 10.
147. C. Lardier, "Mission Altair: Un Francais A Bord De Mir", Air & Cosmos, 12-25 July 1993, p. 80.



148. ITAR-TASS News Agency, 3-5 July 1993.
149. J.M. Lenorovitz, "Russian Capsule Returns Data from Mir Space Station", Aviation Week and Space Technology, 12 July 1993, pp. 25, 28.
150. ITAR-TASS News Agency, 4, 5, 6, 9, 13, and 22 July 1993.
151. N. Kidger, "Mir Mission Report", Spaceflight, May 1994, pp. 152-156.
152. Novosti Kosmonavtiki, 5-18 July 1993, pp. 9-16 and 19 July - 1 August 1993, pp. 5-9.
153. Novosti Kosmonavtiki, 2-15 August 1993, pp. 5-9.
154. M. Rebrov, Krasnaya Zvezda, 14 July 1993, p. 1.
155. ITAR-TASS News Agency, 11 and 13 August 1993.
156. Krasnaya Zvezda, 15 September 1993, p. 1.
157. V. Kamyshev, Gudok, 16 September 1993, p. 3.
158. ITAR-TASS News Agency, 16 and 20 September 1993.
159. Moskovskaya Pravda, 23 September 1993, p. 8.
160. Novosti Kosmonavtiki, 13-26 September 1993, pp. 5-14.
161. Ostankino Channel 1 TV, 28 September 1993.
162. Novosti Kosmonavtiki, 25 September - 8 October 1993, pp. 5-12.
163. Russia's Radio, 8 October 1993.
164. V. Baberdin, Krasnaya Zvezda, 15 October 1993, p. 3.
165. ITAR-TASS News Agency, 13 and 14 October 1993.
166. Novosti Kosmonavtiki, 9-22 October 1993, pp. 5-10.
167. "Russia Launches Boeing Experiment To Mir", Aviation Week and Space Technology, 18 October 1993, p. 30.
168. B. Iannotta, "Firms Test Crystal Technology, Delivery Aboard Mir", Space News, 18 October 1993, p. 26.
169. Novosti Kosmonavtiki, 23 October - 5 November 1993, pp. 5-12.
170. ITAR-TASS News Agency, 22 and 29 October 1993.
171. ITAR-TASS News Agency, 21 November 1993.

172. "Boeing, Energia Retrieve Crystals Grown Aboard Mir", Space News, 3-9 January 1994, p. 13.
173. Novosti Kosmonavtiki, 6-19 November 1993, pp. 5-9; 20 November - 3 December 1993, pp. 6-9; 4-17 December 1993, pp. 6-9; and 18-31 December 1993, pp. 7-12.
174. Moskovskaya Pravda, 23 December 1993, p. 15.
175. ITAR-TASS News Agency, 15 December 1993.
176. Krasnaya Zvezda, 3 August 1993, pp. 1-2.
177. V. Ivanov, Trud, 6 August 1993, p. 4.
178. Europe and Asia in Space 1991-1992, pp. 68-69.
179. M. Rebrov, Krasnaya Zvezda, 31 July 1993, p. 3.
180. V. Baberdin, Krasnaya Zvezda, 6 January 1994, p. 3.
181. ITAR-TASS News Agency, 17 December 1993.
182. V. Kamyshev, Gudok, 31 December 1993, p. 4.
183. ITAR-TASS News Agency, 7, 8, 10, 12, and 14 January 1994.
184. V. Baberdin, Krasnaya Zvezda, 20 January 1994, p. 1.
185. ITAR-TASS News Agency, 4 February 1994.
186. V. Chernobrov, Rossiyskiye Vesti, 21 January 1994, p. 8.
187. M. Chernyshev, Segodnya, 26 January 1994, p. 1.
188. Novosti Kosmonavtiki, 1-14 January 1994, pp. 7-25.
189. S. Leskov, Izvestiya, 19 January 1994, p. 3.
190. V. Baberdin, Krasnaya Zvezda, 26 February 1994, p. 3.
191. Moskovskaya Pravda, 28 January 1994, p. 15.
192. ITAR-TASS News Agency, 28 and 30 January 1994.
193. Novosti Kosmonavtiki, 15-28 January 1994, pp. 6-11.
194. Izvestiya, 12 January 1994, p. 3.
195. D. Kholodov, Moskovskiy Komsomolets, 19 January 1994, p. 1.

196. ITAR-TASS News Agency, 2, 3, and 22 March 1993.
197. Novosti Kosmonavtiki, 29 January - 11 February 1994, pp. 5-8; 12-25 February 1994, pp. 5-8; 26 February - 11 March 1994, pp. 8-13; and 12-25 March 1994, pp. 5-9.
198. ITAR-TASS News Agency, 22-24 March 1994.
199. C. Covault, "Mir Fires Beams At Swedish Satellite", Aviation Week and Space Technology, 4 April 1994, pp. 71-72.
200. ITAR-TASS News Agency, 1 April 1994.
201. ITAR-TASS News Agency, 17, 20, 22, 23, and 24 May 1994.
202. Novosti Kosmonavtiki, 26 March - 8 April 1994, pp. 6-10; 9-22 April 1994, pp. 7-10; 23 April - 6 May 1994, pp. 5-7; and 7 May - 3 June 1994, pp. 6-12.
203. Kazakh TV, 5 May 1994.
204. Radio Moscow, 8 June 1994.
205. ITAR-TASS News Agency, 17 June 1994.
206. Vozdushnyy Transport, July 1994, p. 11.
207. S. Novikov, Segodnya, 16 June 1994, p. 9.
208. O. Volkov, Novaya Yezhednevnyaya, 1 July 1994, p. 2.
209. U. Sultangazin, Sovety Kazakhstana, 30 July 1994, p. 2.
210. Novosti Kosmonavtiki, 4 June - 1 July 1994, pp. 8-14 and 2-15 July 1994, pp. 5-21.
211. M. Rebrov, Krasnaya Zvezda, 1 July 1994, p. 1; 5 July 1994, p. 3; and 12 July 1994, p. 1.
212. ITAR-TASS News Agency, 3 July 1994.
213. ITAR-TASS News Agency, 25, 27, and 29 August 1994.
214. Novosti Kosmonavtiki, 13-26 August 1994, pp. 11-14 and 27 August - 9 September 1994, pp. 5-19.
215. ITAR-TASS News Agency, 30 August and 1-2 September 1994.
216. J.M. Lenorovitz, "Russians Cite Radar for Mir Docking Woes", Aviation Week and Space Technology, 12 September 1994, p. 77.
217. A. Lawler, "Progress Mission Rescued", Space News, 5-11 September 1994, pp. 1, 20.

218. ITAR-TASS News Agency, 9 and 13 September 1994.
219. "Mir Undamaged By Progress Bump", Aviation Week and Space Technology, 19 September 1994, p. 71.
220. Novosti Kosmonavtiki, 10-23 September 1994, pp. 5-12.
221. V. Khrustov, Rossiyskiye Vesti, 10 September 1994, p. 1.
222. ESA Press Release Nr. 16-94, ESA, 30 May 1994.
223. ITAR-TASS News Agency, 4 October 1994.
224. Novosti Kosmonavtiki, 24 September - 7 October 1994, pp. 5-21.
225. ITAR-TASS News Agency, 5 and 6 October 1994.
226. V. Golovachev, Trud, 7 October 1994, p. 2.
227. Interfax News Agency, 26 August 1993.
228. "ESA Astronauts for Mir", Spaceflight, September 1994, pp. 305-307.
229. N. Kidger, "Mir Mission Report", Spaceflight, February 1995, pp. 53-59.
230. "Summary of Experiments: Mir 16 and Euromir Crews", press release, NPO Energia Ltd, 10 November 1994.
231. C. Covault, "ESA/Russia Flight Opens New Space Station Era", Aviation Week and Space Technology, 26 September 1994, pp. 84-85.
232. C. Lardier, "Euromir-94 Doit Etre Lance Le 3 Octobre", Air & Cosmos, 30 September 1994, pp. 30-31.
233. "European Astronauts for Mir", Spaceflight, March 1994, pp. 76-77.
234. I. Parker, "Euromir in Focus", Space, January-February 1995, pp. 12-16.
235. D. Pogorzelskiy, Novoye Vremya, October 1994, pp. 24-25.
236. J.W. Powell, "Euromir 94: Longest European Spaceflight", Countdown, March/April 1995, pp. 40-41.
237. Interfax News Agency, 12 October 1994.
238. Radio Moscow, 13 October 1994.
239. ITAR-TASS News Agency, 14 and 18 October 1994.
240. S. Leskov, Izvestiya, 14 October 1994, p. 1.
241. Novosti Kosmonavtiki, 8-21 October 1994, pp. 5-16.

242. B. Iannotta, "Power Shortage Forces Crew at Mir To Rely on Backup", Space News, 24 October 1994, p. 9.
243. "Mir Faces New Woes", Aviation Week and Space Technology, 24 October 1994, p. 25.
244. P.B. de Selding, "Furnace Failure Could Threaten Mir Research", Space News, 31 October - 6 November 1994, pp. 3, 21.
245. "Mir Furnace Failure Fallout", Space News, 14-20 November 1994, p. 17.
246. Novosti Kosmonavtiki, 22 October - 4 November 1994, pp. 8-19.
247. Interfax News Agency, 2 November 1994.
248. ITAR-TASS News Agency, 2 November 1994.
249. V. Baberdin, Krasnaya Zvezda, 2 November 1994, p. 1.
250. C. Covault, "Crew Test Mir's Docking System", Aviation Week and Space Technology, 7 November 1994, p. 66.
251. ITAR-TASS News Agency, 4 and 6 November 1994.
252. ITAR-TASS News Agency, 11 and 13 November 1994.
253. Novosti Kosmonavtiki, 5-18 November 1994, pp. 6-15.
254. ITAR-TASS News Agency, 17 November 1994.
255. ITAR-TASS News Agency, 10 May 1994.
256. ITAR-TASS News Agency, 13 May 1994.
257. ITAR-TASS News Agency, 18 February 1994.
258. V. Baberdin, Krasnaya Zvezda, 22 February 1994, p. 1 and 15 July 1994, p. 2.
259. ITAR-TASS News Agency, 20 June and 1 September 1994.
260. V. Romanenkova, Segodnya, 1 September 1994, p. 9.
261. Rossiyskaya Gazeta, 14 January 1994, p. 1.
262. ITAR-TASS News Agency, 2 February 1994.

## 4.0 EARTH APPLICATIONS PROGRAMS

The overwhelming majority of operational satellites are devoted to Earth applications programs in the fields of communications, navigation, geodesy, Earth observation and remote sensing, and materials science. By their very nature, these missions may be sponsored by civil, military, or government agencies or may support multiple users. Earth applications spacecraft may range in mass from 50 kg to nearly 20,000 kg and may be short-lived in orbits as low as 150 km or may be operational for ten years or more in orbits as high as 36,000 km. Perhaps more importantly, Earth applications satellites are operated by more nations and international organizations than any other class of spacecraft.

### 4.1 COMMUNICATIONS

Space-based communications systems continue to represent the major area of satellite applications for all Eurasian countries. For many non-launching countries, communications satellites constitute their only national space systems. Globally, more than half of all operational spacecraft are devoted to telecommunications. Of the 124 European and Asian space launch attempts conducted during 1993-1994, more than one-third carried at least one communications spacecraft for either domestic or commercial purposes. The vast majority of these spacecraft are placed in geosynchronous orbits, and by the end of 1994 a total of 123 GEO communications spacecraft were in service for European and Asian operators (Table 4.1).

#### 4.1.1 European Space Agency

Telecommunications not only was the subject of ESA's first Earth applications satellite program but also has remained a high priority of the organization. Although only a few ESA GEO communications satellites were operational during 1993-1994, the influence of ESA has been far greater due to the transfer of spacecraft to the fledgling EUTELSAT and INMARSAT programs. Throughout its history ESA has focused on communications technology development rather than network operations. One of the agency's three major satellite engineering programs is the Data Relay Satellite (DRS) scheduled for launch near the end of this decade.

The Orbital Test Satellite (OTS) program was inherited by ESA in 1975 from its predecessor, the European Space Research Organization (ESRO). Two of the experimental spacecraft were built, but the first vehicle was lost during a Delta launch failure in 1977. The following year OTS-2 became one of the first GEO communications satellite to carry six Ku-band (14/11 GHz) transponders and was capable of handling 7,200 telephone circuits. With a mass of approximately 445 kg on station, the OTS-2 bus was hexagonal with overall dimensions of 2.4 m by 2.1 m. Two solar panels with a span of 9.3 m provided 0.6 kW of electrical power. British Aerospace was the prime contractor from the European MESH consortium which developed the OTS vehicle. OTS-2 completed its primary mission in 1984 after which the spacecraft was involved in a 6-year program of experiments, including the testing of a new attitude control technique taking advantage of solar wind forces. In January, 1991, OTS-2 was moved out of the geostationary ring and into a graveyard orbit (Reference 1).

Based on the OTS experience, ESA developed and launched the European Communications Satellite (ECS) and the Maritime ECS (MARECS) in the early 1980's. These assets were later transferred or leased to the EUTELSAT and INMARSAT organizations, respectively. In all, six satellites of this class were successfully launched under sponsorship of ESA during the period 1981-1988, and at the end of 1994 five were still in active or reserve status.

MARECS spacecraft are roughly 0.55 metric tons on-station and have a design life of 7 years, although both deployed MARECS vehicles have exceeded that goal. The primary payload consists of 6/4 GHz and 1.6/1.5 GHz transponders for fixed and mobile users, respectively. Only three MARECS spacecraft were built, and the second, MARECS B1, was lost in a launch accident in 1982.

At the end of 1994 MARECS A was no longer in service but was the subject of mobile communications testing near 22.5° E. (Reference 2). MARECS B2 continues to support INMARSAT from its location at 15.2° W (Atlantic Ocean East region).

ESA's Olympus communications technology test bed (formerly known as L-Sat) was

TABLE 4.1 GEOSYNCHRONOUS COMMUNICATIONS SATELLITES.

COUNTRY / ORGANIZATION	SPACE SYSTEM	YEAR OF DEBUT	1993-1994 MISSIONS (1)	OPERATIONAL SATELLITES (2)
ESA	MARECS	1981	0	2
EUTELSAT	EUTELSAT 1	1983	0	3
	EUTELSAT 2	1990	1	4
FRANCE	TDF	1988	0	2
	TELECOM 1	1984	0	1
	TELECOM 2	1991	0	2
GERMANY	DFS	1989	0	3
	TV-SAT	1987	0	1
HONG KONG	APSTAR	1994	1	1
	ASIASAT	1990	0	1
INDIA	INSAT 1	1982	0	1
	INSAT 2	1992	1	2
INDONESIA	PALAPA B	1983	0	4
INMARSAT	INMARSAT 2	1990	0	4
INTELSAT	INTELSAT 5	1980	0	7
	INTELSAT 5A	1985	0	5
	INTELSAT 6	1989	0	5
	INTELSAT 7	1993	3	3
	INTELSAT K	1992	0	1
ITALY	ITALSAT	1991	0	1
JAPAN	BS-3	1990	1	3
	CS-3	1988	0	2
	ETS	1987	1	1
	JCSAT	1989	0	2
	SUPERBIRD	1992	0	2
LUXEMBOURG	ASTRA 1	1988	2	4
NATO	NATO 3	1976	0	1
	NATO 4	1991	1	2
NORWAY	THOR (3)	1992	0	1
PRC	CHINA SAT (4)	1993	1	1
	DFH-2	1988	0	3
	DFH-3	1994	1	0
RUSSIAN FEDERATION	EKRAN	1976	0	2
	EXPRESS	1994	1	1
	GALS	1994	1	1
	GORIZONT (5)	1978	4	13
	LUCH	1985	1	2
	POTOK	1982	1	4
	RADUGA	1975	4	10
	RADUGA 1	1989	1	3
SAUDI ARABIA	ARABSAT 1	1985	0	2
SPAIN	HISPASAT 1	1992	1	2
SWEDEN	SIRIUS (6)	1994	1	1
	TELE-X	1989	0	1
THAILAND	THAICOM	1993	2	2
TURKEY	TURKSAT 1	1994	2	1
UNITED KINGDOM	SKYNET 4	1990	0	3
		TOTAL	32	123

(1) Includes launch failures

(2) As of 31 December 1994

(3) Satellite launched as Marcopolo 2 in 1990

(4) Satellite launched as Spacenet 1 in 1984

(5) Includes Gorizonts 17, 29, and 30 operated by Rimsat, Ltd, under a lease from Tonga

(6) Satellite launched as Marcopolo 1 in 1989

TABLE 4.2 PRINCIPAL EURASIAN GEO COMMUNICATIONS SPACECRAFT, 1 JANUARY 1995.

DEG E	SPACECRAFT	OPERATOR
3.0	TELECOM 1C	FRANCE
5.0	TELE X	SWEDEN
5.4	SIRIUS	SWEDEN
6.0	NATO 4B	NATO
7.0	EUTELSAT 2 F4	EUTELSAT
10.0	EUTELSAT 2 F2	EUTELSAT
12.0	RADUGA 22	RUSSIA
12.0	RADUGA 29	RUSSIA
13.0	EUTELSAT 2 F1	EUTELSAT
13.2	ITALSAT 1	ITALY
16.0	EUTELSAT 2 F3	EUTELSAT
19.2	ASTRA 1A	LUXEMBOURG
19.2	ASTRA 1B	LUXEMBOURG
19.2	ASTRA 1C	LUXEMBOURG
19.2	ASTRA 1D	LUXEMBOURG
20.0	ARABSAT 1D	SAUDI ARABIA
21.5	EUTELSAT 1 F5	EUTELSAT
22.5	MARECS A	ESA
23.5	DFS 3	GERMANY
25.5	EUTELSAT 1 F4	EUTELSAT
28.5	DFS 2	GERMANY
31.0	ARABSAT 1C	SAUDI ARABIA
33.0	DFS 1	GERMANY
35.0	RADUGA 28	RUSSIA
40.0	GORIZONT 22	RUSSIA
42.0	TURKSAT 1B	TURKEY
45.0	RADUGA 31	RUSSIA
48.0	EUTELSAT 1 F1	EUTELSAT
49.0	RADUGA 1-2	RUSSIA
49.0	RADUGA 1-3	RUSSIA
53.0	GORIZONT 27	RUSSIA
53.0	SKYNET 4B	UK
57.0	INTELSAT 507	INTELSAT
60.0	INTELSAT 604	INTELSAT
63.0	INTELSAT 602	INTELSAT
64.5	INMARSAT 2 F1	INMARSAT
64.9	INTELSAT 505	INTELSAT
66.0	INTELSAT 510	INTELSAT
70.0	RADUGA 25	RUSSIA
70.0	RADUGA 32	RUSSIA
70.0	RADUGA 1-1	RUSSIA
70.0	EXPRESS 1	RUSSIA

DEG E	SPACECRAFT	OPERATOR
71.0	GALS 1	RUSSIA
74.0	INSAT 2A	INDIA
78.5	THAICOM 2	THAILAND
78.5	THAICOM 1	THAILAND
80.0	GORIZONT 24	RUSSIA
80.0	KOSMOS 2085	RUSSIA
80.0	KOSMOS 2291	RUSSIA
83.0	INSAT 1D	INDIA
85.0	RADUGA 30	RUSSIA
87.5	DFH 2 F1	PRC
90.0	GORIZONT 28	RUSSIA
91.5	INTELSAT 501	INTELSAT
93.5	INSAT 2B	INDIA
95.0	LUCH 1	RUSSIA
96.5	GORIZONT 19	RUSSIA
98.0	DFH 2 F3	PRC
99.0	EKRAN 19	RUSSIA
99.0	EKRAN 20	RUSSIA
103.0	GORIZONT 25	RUSSIA
105.5	ASIASAT 1	HONG KONG
108.0	PALAPA B2R	INDONESIA
110.0	BS-3N	JAPAN
110.0	BS-3B	JAPAN
110.0	BS-3A	JAPAN
110.5	DFH 2 F2	PRC
113.0	PALAPA B2P	INDONESIA
115.5	CHINASAT 5	PRC
118.0	PALAPA B4	INDONESIA
128.0	RADUGA 27	RUSSIA
130.0	GORIZONT 29	RUSSIA*
132.0	CS-3A	JAPAN
134.0	PALAPA B1	INDONESIA
134.0	GORIZONT 17	RUSSIA*
136.0	CS-3B	JAPAN
138.0	APSTAR 1	PRC
140.0	GORIZONT 18	RUSSIA
142.5	GORIZONT 30	RUSSIA*
145.0	GORIZONT 21	RUSSIA
150.0	JCSAT 1	JAPAN
150.0	ETS-V	JAPAN
154.0	JCSAT 2	JAPAN
158.0	SUPERBIRD A1	JAPAN

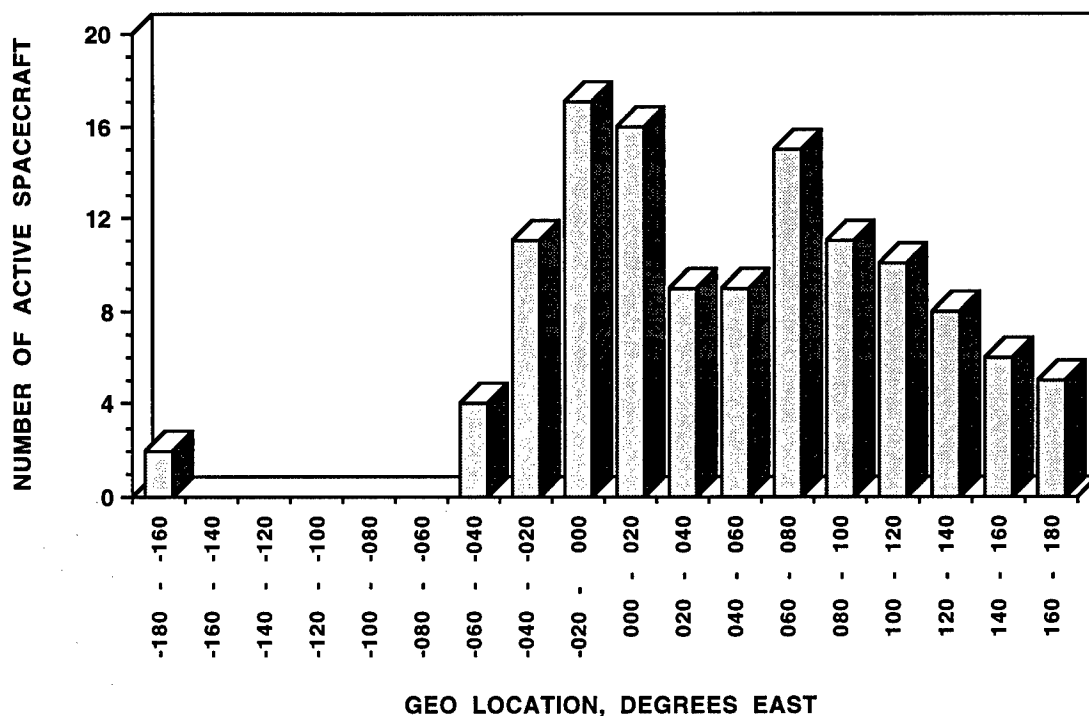
\* Leased to Rimsat



TABLE 4.2 PRINCIPAL EURASIAN GEO COMMUNICATIONS SPACECRAFT,  
1 JANUARY 1995 (continued).

DEG E	SPACECRAFT	OPERATOR
162.0	SUPERBIRD B1	JAPAN
174.0	INTELSAT 701	INTELSAT
177.0	INTELSAT 703	INTELSAT
178.0	INMARSAT 2 F3	INMARSAT
180.0	INTELSAT 511	INTELSAT
183.0	INTELSAT 503	INTELSAT
190.0	RADUGA 21	RUSSIA
305.0	INMARSAT 2 F4	INMARSAT
307.0	INTELSAT 513	INTELSAT
310.0	INTELSAT 506	INTELSAT
319.5	INTELSAT 502	INTELSAT
325.5	INTELSAT 603	INTELSAT
326.0	SKYNET 4A	UK
328.6	INTELSAT 504	INTELSAT
330.0	HISPASAT 1B	SPAIN
330.0	HISPASAT 1A	SPAIN
332.5	INTELSAT 601	INTELSAT
335.0	RADUGA 23	RUSSIA
335.5	INTELSAT 605	INTELSAT
338.5	INTELSAT 512	INTELSAT

DEG E	SPACECRAFT	OPERATOR
338.5	INTELSAT K	INTELSAT
339.0	NATO 3D	NATO
340.8	TVSAT 2	GERMANY
341.0	TDF 2	FRANCE
341.0	TDF 1	FRANCE
342.0	INTELSAT 515	INTELSAT
342.0	NATO 4A	NATO
344.0	KOSMOS 2054	RUSSIA
344.5	INMARSAT 2 F2	INMARSAT
344.8	MARECS B2	ESA
346.0	GORIZONT 20	RUSSIA
346.5	KOSMOS 1888	RUSSIA
346.5	KOSMOS 2172	RUSSIA
349.0	GORIZONT 26	RUSSIA
352.0	TELECOM 2A	FRANCE
355.0	TELECOM 2B	FRANCE
359.0	INTELSAT 702	INTELSAT
359.0	THOR 1	NORWAY
359.0	SKYNET 4C	UK



launched by an Ariane 3 in July, 1989, and stationed near 19° W. The on-station mass of Olympus was 1.5 metric tons with a payload of 360 kg, including two 18/12 GHz, 230 W transponders; three 30/20 GHz, 30 W transponders; and four 14/12 GHz, 30 W transponders. The spacecraft bus was approximately 2.6 m by 2.1 m by 1.8 m with two 27.5 m solar arrays capable of a minimum of 3.6 kW at end of life. The prime contractor was British Aerospace with major contributions from Alenia Spazio, Fokker, Matra Marconi, and Spar Aerospace Ltd. The principal ESA participants in the Olympus program were Austria, Belgium, Canada, Denmark, Italy, Netherlands, Spain, and the United Kingdom.

Olympus (Figure 4.1) suffered several setbacks in 1991 but was eventually able to recover. In late January one of the two solar arrays lost its ability to track the sun. Then, four months later, an attitude control upset was compounded by improper commands from the Fucino ground station, causing failures in the electrical, propulsion, and thermal control systems. The spacecraft drifted in GEO for two months before the vehicle could be brought under control. Olympus was maneuvered back to 19° W by mid-August, 1991, and the individual payloads were reactivated during September-November (References 3-8).

The hard-luck Olympus failed to meet its 5-year operational goal when on the night of 11-12 August 1994 the spacecraft was apparently hit by a meteor during the annual Perseid

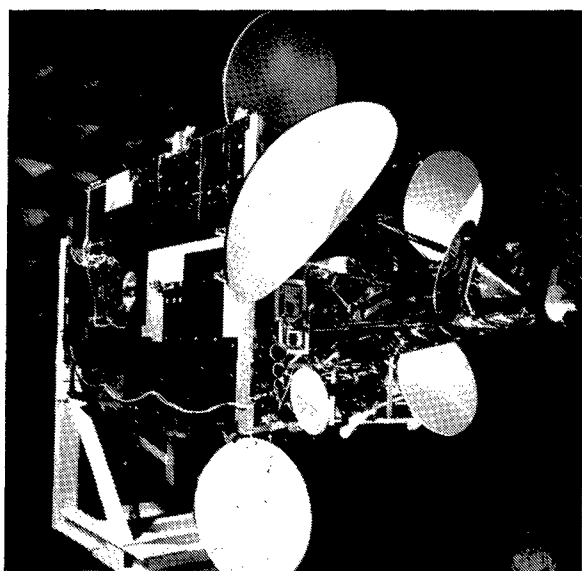


FIGURE 4.1 OLYMPUS SPACECRAFT.

shower. Although still functional, the spacecraft experienced an attitude control upset which ultimately consumed a substantial portion of the remaining propellants. The situation was compounded by the automatic control system actions which sent the vehicle into a lower altitude drift orbit. Since insufficient propellant was left to recover the spacecraft completely, ESA controllers reduced Olympus' altitude even more, placing it in a graveyard orbit (References 9-11).

ESA's Data Relay and Technology Mission (DRTM) has been divided into two principal efforts: the Advanced Relay Technology Mission (ARTEMIS) and the aforementioned DRS. ARTEMIS, whose launch has been delayed until late 1997 at the earliest, will serve as a pathfinder for DRS with three principal payloads:

- (1) Semiconductor Intersatellite Link Experiment (SILEX) optical terminal to demonstrate space-to-space links with the French SPOT 4 spacecraft;
- (2) L-band transponder to provide land-mobile communications within Europe; and
- (3) S-band (2 GHz) and Ka-band (23-28 GHz) data relay equipment for pre-DRS experiments.

The spacecraft will also test two independent ion thruster systems for orbital maintenance over a potential 10-year life-span.

In 1993 Alenia Spazio was awarded the prime contract for ARTEMIS which will be based on the ITALSAT design with a mass of 2.6 metric tons, including 1.2 metric tons of propellant. The 3-axis-stabilized spacecraft will feature two elongated solar arrays with an end-of-life capacity of at least 2.8 kW (Figure 4.2). The payload, with a mass of up to 550 kg, will employ two 2.85-m-diameter and one 1.0-m-diameter antennas for the L-, S-, and Ka-band transponders. A 1-m-diameter telescope will be installed at the Teide Observatory, Tenerife, the Canary Islands to support SILEX experiments. Originally scheduled to fly on the second Ariane 5 mission in 1996, ARTEMIS has encountered serious technical and cost problems, leading at least one ESA member to consider abandoning the project (References 12-22).

Alenia Spazio is also the proposed prime contractor for DRS which has suffered a lack of ESA Council support since its reaffirmation at the November, 1991, ministerial meeting in



FIGURE 4.2 ARTEMIS SPACECRAFT.

Granada. Through 1994 the detailed definition phase (Phase B2) for DRS was underway, but a move into the main development phase (Phase C/D) was delayed pending programmatic decisions. If fully approved in 1995, the first of two spacecraft might be launched as early as 1999 with payloads similar to ARTEMIS' SILEX and S-/Ka-band equipment (Figure 4.3). A full DRS constellation will consist of spacecraft stationed at  $59^{\circ}$  E and  $44^{\circ}$  W. ARTEMIS will join the DRS to support SPOT, ENVISAT, the International Space Station and other selected spacecraft, including military spacecraft (References 12-13, 23-29).

ESA is also looking at a variety of other satellite communications projects. Under the ESA Payload and Spacecraft Demonstration and Experimentation Program (PSDE), development of a European Mobile Services (EMS) system is underway for a test flight as an auxiliary payload of ITALSAT F2, now scheduled for launch in 1995. The Advanced Orbital Test Satellite System (AOTS) may introduce ESA's first communications satellite in a highly elliptical, inclined orbit. Named Archimedes, the new system would be designed primarily for portable receivers at high latitudes. First launch of up to six spacecraft could begin by the end of the decade (References 3, 12, 13, 30-32).

ESA is also promoting satellite communications technology under the Advanced Research in Telecommunications Systems (ARTES) program, which had grown to 12 elements by the end of 1994. These elements include the On-Board Processing mission, the Multi-Orbit Small Satellite program, and the Little LEO Messaging System. The last could witness the launch of a first payload as early as 1996. In addition, ESA is a proponent of general satellite communications research (References 3, 12, 13, 28, 33-35).

#### 4.1.2 EUTELSAT

The European Telecommunications Satellite Organization (EUTELSAT) has been servicing the European community since 1977, being formally established by a multi-lateral agreement in 1985. By end 1994, the organization had grown to 44 members, primarily due to the breakup of the former Soviet Union and the restructuring of Europe. Some of the more recent members are the Russian Federation, Estonia, Latvia, Moldova, Bulgaria, Andorra, and Belarus.

In 1979 ESA agreed to design, build, and launch five ECS spacecraft to be assumed by EUTELSAT after passing initial on-orbiting testing. At that time the name of each spacecraft was changed to EUTELSAT 1-F1, EUTELSAT 1-F2, etc. Of the five ECS spacecraft, four were successfully launched (1983, 1984, 1987, and 1988) and transferred to EUTELSAT. ECS 3 was lost in an Ariane launch accident in 1985.

As noted previously, the ECS spacecraft was derived from the OTS vehicle but with an initial mass on station of approximately 700 kg.

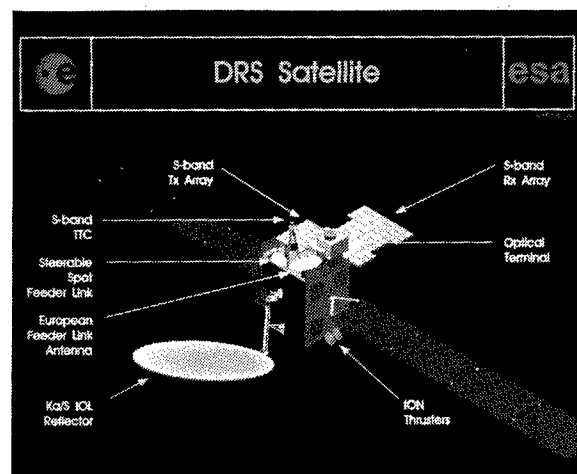


FIGURE 4.3 DRS SPACECRAFT.

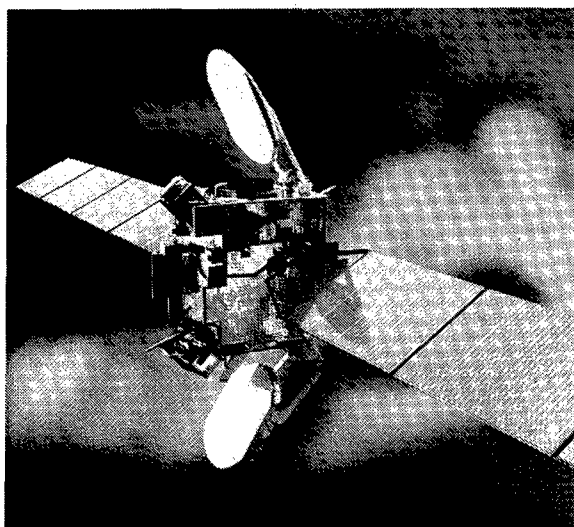


FIGURE 4.4 EUTELSAT 2 SPACECRAFT.

The payload included twelve (including two spares) 14/11 GHz transponders with 20 W output power for a capacity of 12,000 telephone circuits or 10 television channels. Two solar arrays with a span of 13.8 m provided 1 kW of electrical power to the 2.2 m by 2.4 m spacecraft bus. With an anticipated working life of up to seven years, at the end of 1994 three ECS/EUTELSAT 1 spacecraft were still operational at 21.5° E, 25.5° E, and 48° E, although EUTELSAT 1-F1 offered limited service due to its inclination of more than 4.5°. EUTELSAT 1-F2 (ECS 2) was retired in December, 1993.

In 1990 EUTELSAT began the deployment of the second generation EUTELSAT spacecraft procured directly from Aerospatiale and based on the Spacebus-100 design. Each EUTELSAT 2 spacecraft supports 16 transponders (with eight spares) operating at 14/11 GHz and 50 W output power. In orbit the spacecraft spans 22.4 m across the two rectangular solar arrays which generate up to 3.5 kW. Although similar in appearance to EUTELSAT 1, EUTELSAT 2 employs two, 1.6 m diameter multifeed reflectors, one on each side of the spacecraft bus (Figure 4.4).

Throughout 1993-1994, the EUTELSAT 2 constellation consisted of four spacecraft: No. 1 at 13° E, No. 2 at 10° E, No. 3 at 16° E, and No. 4 at 7° E. EUTELSAT 2-F5 was scheduled to join the network in 1994 but was lost in an Ariane launch accident on 24 January 1994. The last of the EUTELSAT 2 series spacecraft was scheduled for launch in 1995 under the name

Hotbird 1. The vehicle will be essentially the same as its predecessors, but the transponder output power will be increased from 50 W to 70 W (References 36-37).

In late 1993 EUTELSAT sought bids for a more capable spacecraft dubbed Hotbird Plus. In early 1994, Matra Marconi was awarded the contract for a single spacecraft, Hotbird 2, with options for up to three more. By the end of 1994 the first option had been exercised for Hotbird 3. The new spacecraft will be launched in 1996 and 1997 and will be based on the Eurostar design developed jointly by British Aerospace and Matra Marconi. The nearly 3-metric-ton Hotbird Plus will carry 20 high power (110 W) Ku-band transponders to permit direct-to-home television broadcast service to Europe via a Superbeam antenna and broader coverage with a Widebeam antenna. An enlarged solar array will generate the 5.5 kW required by the spacecraft and its power-hungry payload. The new Hotbird Plus spacecraft will be co-located with Hotbird 1 at 13° E (References 38-42).

The Hotbird series of spacecraft represent a stop-gap measure before the even larger, more capable EUTELSAT 3 satellites are deployed. In late 1994 EUTELSAT requested bids for the new spacecraft which are expected to have a mass of three metric tons in order to carry 24 active 90 W, Ku-band transponders (reduced from an initial goal of 34 transponders). An award for the first batch of EUTELSAT 3 spacecraft, to be ready beginning in 1998, was anticipated in 1995 (References 43-45).

EUTELSAT had planned to create a new generation of direct broadcast satellites, called Europesat, for operations starting in the mid-1990's. Sponsored primarily by France and Germany, the project faltered when France's Telecom declined to participate. The market envisioned for Europesat was high definition television broadcasting using 125 W, 18/12 GHz transponders (References 46-48).

#### 4.1.3 France

Since 1988 France has operated two national communications systems in GEO, Telecom and TDF, to ensure domestic and international telephone and television service. An advanced communications technology spacecraft, called Stentor, was approved in 1994 for a launch in 1999. Meanwhile, French plans for LEO communications networks faded during 1993-1994, and the lone mini-satellite of

this class launched in early 1993 suffered major problems early in life.

The initial French experience with GEO telecommunications began in 1967 when a joint venture was signed by France and Germany to develop two experimental Symphonie satellites. The small (230 kg) spacecraft with 3-axis stabilization and two 6/4 GHz transponders were launched by the U.S. in 1974 and 1975. The Symphonie system was highly successful in providing telecommunications links throughout Europe and to other continents. Both spacecraft far exceeded the 5-year design life and were transferred to graveyard orbits in 1983 and 1985, respectively.

Shortly before the retirement of Symphonie 2, the first Telecom spacecraft, Telecom 1A, was launched by an Ariane booster on 4 August 1984. Operated by France Telecom under government sponsorship, Telecom satellites service both civilian and military users through twelve active and five reserve transponders operating at 6/4 GHz (four transponders), 14/12 GHz (six transponders), and 8/7 GHz (two transponders). The last units provide the Syracuse (Système de Radio Communications Utilisant un Satellite) secure military channels for the French Ministry of Defense (References 49-50).

Telecom 1 satellites were designed and manufactured by Matra with the communications package supplied by Alcatel Espace. At the start of its 7-year design life, each Telecom 1 had a mass of approximately 700 kg and an initial electrical power capacity of 1.2 kW, supplied by two narrow solar arrays with a total span of 16 m. The spacecraft bus was derived from the earlier ECS program (Section 4.1.2) in which Matra was a subcontractor to British Aerospace. A total of three Telecom 1 satellites were launched (1984, 1985, 1988). Only Telecom 1C remained operational at the end of 1994 and was stationed at 3° E after being moved from 5° W in the Fall of 1992.

The second generation Telecom spacecraft debuted on 16 December 1991 as Telecom 2A and was followed on 15 April 1992 by Telecom 2B. This new series of more capable spacecraft was designed and manufactured jointly by Matra Marconi and Alcatel Espace and is based on the Matra-British Aerospace Eurostar 2000 2.0 x 2.1 x 2.0 m satellite bus (Figure 4.5). On-orbit mass of Telecom 2 is 1380 kg with a payload mass of 400 kg. The twin solar panels span 22 m and provide an excess of 3.6 kW

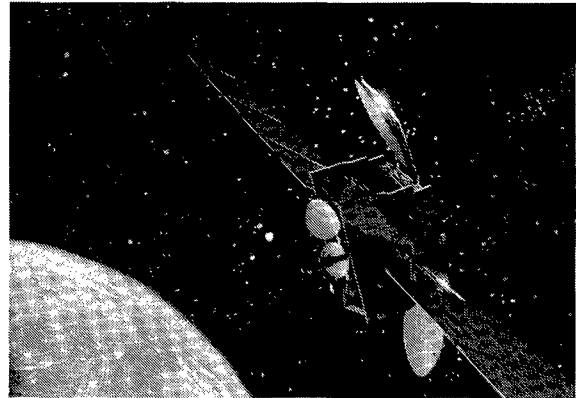


FIGURE 4.5 TELECOM 2 SPACECRAFT.

with 2.5 kW available for the payload. The design life is 10.25 years.

The Telecom 2 communications package includes ten 6/4 GHz transponders with four spares for telephone and television relays, six 8/7 GHz transponders with three spares for the military Syracuse II payload, and 11 14/12 GHz transponders with four spares for television, data transmission, and teleconference. When completed the Telecom 2 constellation will be deployed at 8° W, 5° W, and 3° E. At the end of 1994 Telecom 2A and 2B were stationed at 8° W and 5° W, respectively. The launch of Telecom 2C was scheduled for 1995 with Telecom 2D set to follow as early as the latter part of 1996. Studies for a proposed third generation Telecom series are underway (References 51-54).

A 1980 French-German agreement to develop compatible direct broadcast satellite systems led to the creation of the French TDF (Telediffusion de France) series of satellites which were launched in 1988 and 1990 (References 55-56). Based on Aerospatiale's Spacebus 300 platform, TDF spacecraft are about 1.3 metric tons on station with bus dimensions of 1.6 m by 2.4 m by 7.1 m and a payload mass of 250 kg (Figure 4.6). The solar arrays span 19.3 m and provide 4.3 kW at start of life. Both spacecraft carry five, high power (230 W) 18/12 GHz transponders and are located at 19° W. A decision to delete a third spacecraft from the program was based, in part, on the assumption that Europesat would be available in the late 1990's (Section 4.1.2).

Matra Marconi's S80/T microsatellite (Figure 4.7), based on the UK UoSAT bus, was placed into a nearly circular orbit of 1,315 km at an inclination of 66.1° as a piggyback payload

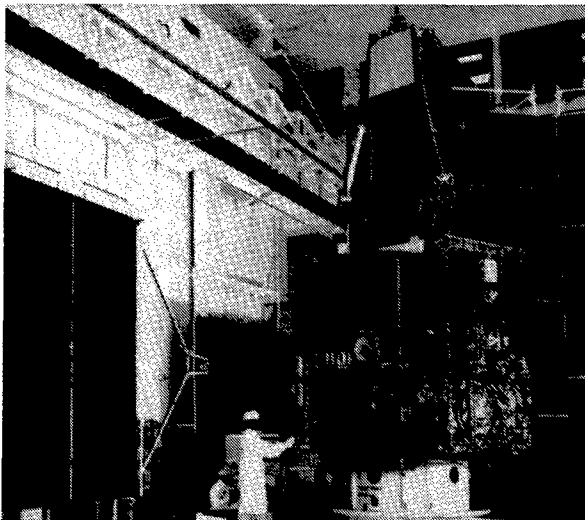


FIGURE 4.6 TDF SPACECRAFT.

on the Topex/Poseidon mission in August, 1992. Sponsored by CNES, the 50-kg S80/T satellite with a 7 kg payload developed by Dassault Electronique was gravity gradient stabilized with a 25 W power supply. The primary objectives were "analysis of the VHF frequency band between 148 and 149.9 MHz and transmission of data to prepare the future operational S80 system, a constellation of small satellites in

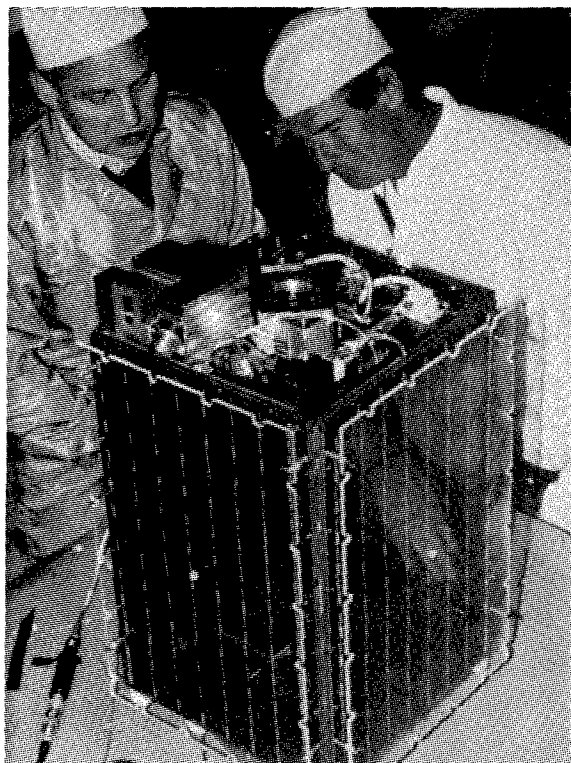


FIGURE 4.7 S80/T SPACECRAFT IN TESTING.

low, inclined orbits providing positioning and short message services" (Reference 57).

The proposed Taos system was to be comprised of 5-12 spacecraft in circular 1,248 km altitude orbits with a 57.1° inclination. The 152-kg spacecraft, similar to S80/T, would be centered on a bus of 0.65 x 0.65 x 0.80 m and four 2-m-long solar panels (Figure 4.8). The VHF payload would account for up to 60 kg. However, Taos did not receive French government support, and the S80/T spacecraft was offered to the International Space University (References 58-63).

Perhaps influencing the Taos decision was the disappointing experience with Arsene, launched on 12 May 1993 into a 17,666 km by 37,041 km orbit as a piggy-back payload on an Ariane GEO mission. More than a decade in the making, Arsene was designed as an amateur radio satellite, but some of its systems were to serve as prototypes for future small communications satellites. Unfortunately, the VHF antenna failed immediately after launch, and operations with the vehicle's SHF antenna ultimately led to power supply problems and loss of the 154-kg spacecraft after only three months in orbit (References 64-66).

After considerable debate, France has chosen the Stentor technology satellite as its next major investment in space-based communications. The GEO spacecraft is scheduled for

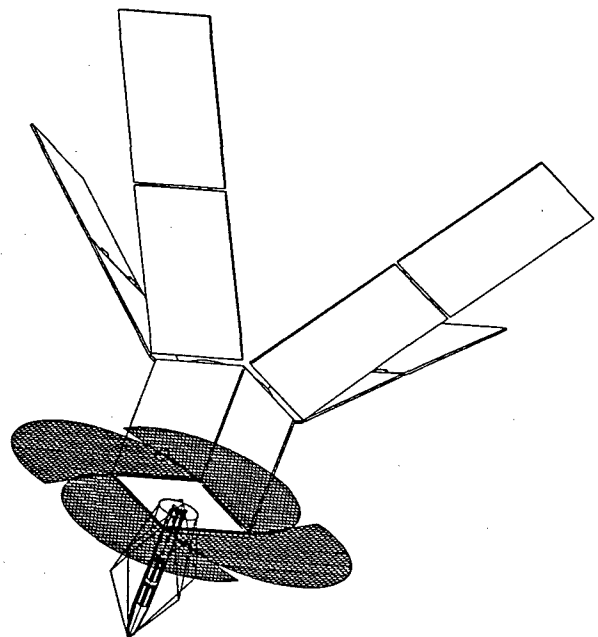


FIGURE 4.8 TAOS SPACECRAFT.

launch by 1999 to test both civil and military communications systems. Originally envisioned as a 2.5 metric-ton satellite, the chosen Stentor design required only 1.5 metric tons at launch. An ion propulsion system alone reduced the spacecraft mass by 600 kg by eliminating a large liquid propellant propulsion system. Gallium arsenide solar cells will provide the 1.8 kW needed to power the satellite and its Ku-band payload. Matra Marconi, Alcatel, and Aerospatiale will bear primary responsibility for the spacecraft (References 67-69).

#### 4.1.4 Germany

German experience with GEO telecommunications has mirrored that of France. As noted in the previous section, Germany was an equal partner with France in the Symphonie program. After gaining space communications relay experience, Germany developed a pair of TV-Sat spacecraft in conjunction with France's TDF program. This was followed by the DFS (Deutscher Fernmeldesatellit) Kopernikus series of communications satellites.

Like the French TDF, TV-Sat satellites are based on the Aerospatiale Spacebus 300 platform and were created by the Eurosatellite consortium of Aerospatiale and Messerschmitt-Boelkow-Blohm (MBB). The technical specifications of TV-Sat are also virtually identical with those of TDF, and both satellites share the same geostationary locale near 19° W. MBB was responsible for the attitude and orbit control systems on both TDF and TV-Sat using the S400 and S10 engines (References 70-71).

TV-Sat 1 was launched on 21 November 1987 but the failure of one solar panel to deploy severely curtailed operations, and the space-

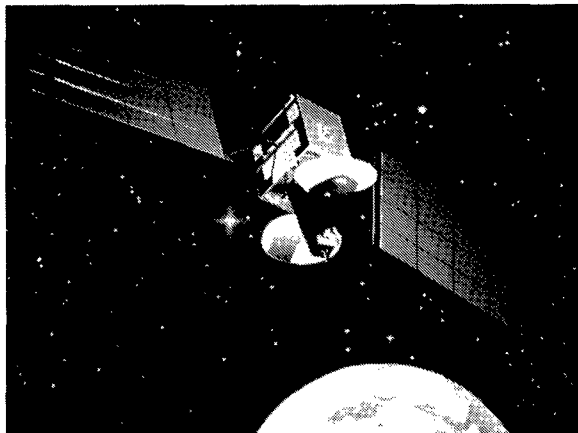


FIGURE 4.9 TV-SAT SPACECRAFT.

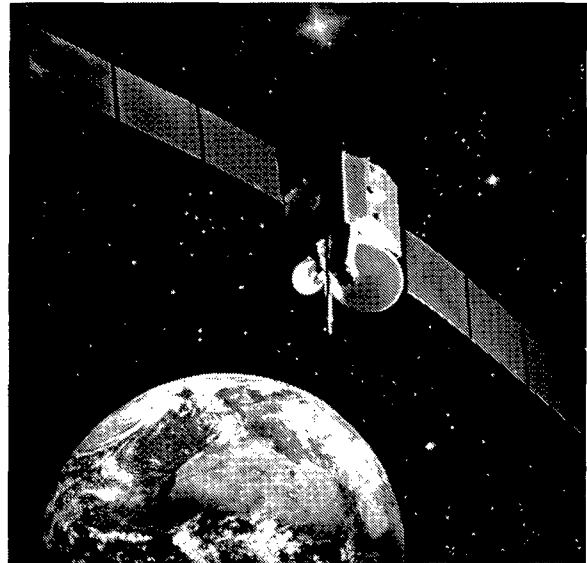


FIGURE 4.10 DFS (KOPERNIKUS) SPACECRAFT.

craft was placed in a graveyard orbit in 1989. TV-Sat 2 followed on 8 August 1989 and is currently on station at 19.2° W. No further launches in this series are planned (References 72-73).

The DFS series of satellites debuted in 1989 with the third being launched in 1992. Produced by the GESAT consortium of MBB (flight segment prime contractor), Siemens (overall prime contractor), ANT Nachrichtentechnik (payload), Standard Elektrik Lorenz (digital switching equipment), and Dornier Systems (ground control system), DFS spacecraft are smaller than TV-Sat: on-station mass of DFS is 850 kg with a 15.4 m solar array span providing up to 1.5 kW of electrical power (Figure 4.10).

The communications payload includes ten 14/11-12 GHz transponders with five spares and one experimental 30/20 GHz transponder with one spare. At the end of 1994 DFS 1-3 were stationed at 33.5° E, 28.5° E, and 23.5° E, respectively. Like TV-Sat, the DFS Kopernikus series has been concluded (References 74-76).

In 1991 The Technical University of Berlin's microsat Tubsat A was carried into a sun-synchronous orbit of approximately 775 km at an inclination of 98.5° during ESA's ERS-1 flight. The 35-kg, 0.4 m cube satellite was designed to test a 1.6/1.5 GHz data relay system for Antarctic platforms. An octagonal Tubsat B with slightly greater dimensions (0.5 m), power (25 W), and mass (40 kg) was launched on 25 January 1994 as a piggy-back satellite with the Russian Meteor 3-6 spacecraft into an orbit of

1,185 km by 1,209 km at an inclination of 82.6°. The principal objective of Tubsat B was space technology experimentation rather than communications, and the spacecraft failed after less than six weeks in orbit.

OHB System and the German Space Agency (DARA) have undertaken a program of small communications satellites named SAFIR (Satellite for Information Relay). The first of the series, SAFIR-R1, was launched on 4 November 1994 attached to the Russian Resurs O-1 spacecraft. The 38-kg package was not released for this initial test of messaging service in a 660-km orbit, but it did carry a Rockwell SpaceNav V GPS receiver. Additional SAFIR-R and free-flying SAFIR spacecraft are scheduled for flights in 1996 and 1997 on board other Russian launch vehicles. The SAFIR spacecraft will have a mass of 55 kg in the form of a 0.45-m cube and a gravity-gradient stabilization system. Communications will be in the 400 MHz band (References 77-78).

Under contract to the Italian firm Telespazio, Germany's Kayser-Threde GmbH designed and built the TEMISAT environmental data collection and relay satellite which was launched in August, 1993 (Section 4.1.13).

#### 4.1.5 Hong Kong

Hong Kong is now the base of operations for two telecommunications organizations responsible for the Asiasat and APStar networks, respectively, providing a wide range of services to Asia and the Western Pacific region. Both systems, however, rely on US-manufactured spacecraft launched on Chinese boosters.

The Hong Kong-based consortium, Asia Satellite Telecommunications Company, including United Kingdom and Chinese partners, entered the commercial telecommunications market in 1990 with the launch of Asiasat 1. Based on Hughes HS-376 platform, Asiasat 1 (Figure 4.11) had been flown in 1984 as Westar 6, but a perigee kick motor malfunction allowed it to be retrieved by the U.S. Shuttle, refurbished, and reflown (see also Indonesia's Palapa B2R). Asiasat 1 marked China's first commercial space launch when a CZ-3 booster placed the spacecraft in a geostationary transfer orbit on 7 April 1990.

Asiasat 1 carries 30 low-power, 6/4 GHz transponders of which as many as 24 are active. The on-orbit mass of the satellite at 105.5° E is just over 600 kg. A more capable

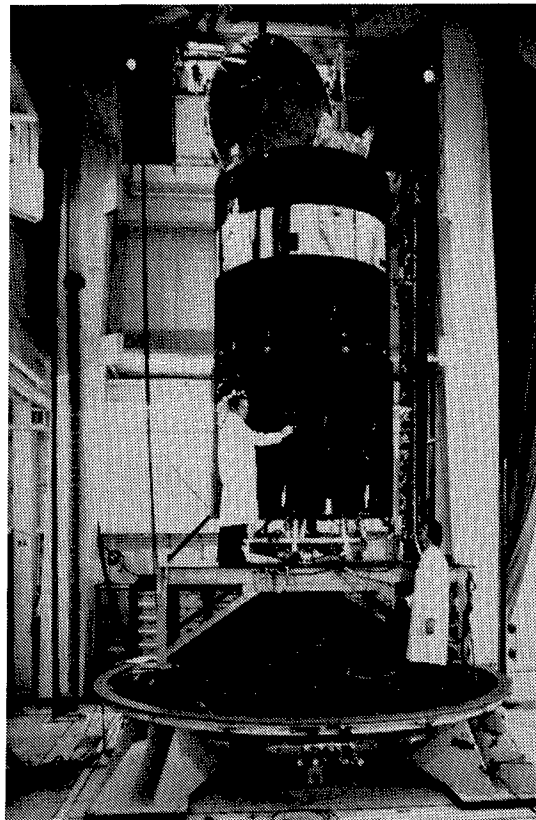


FIGURE 4.11 ASIAsAT 1 SPACECRAFT IN CHECKOUT.

Asiasat 2 is expected to be launched in 1995 and will be based on a Lockheed-Martin 7000 spacecraft bus. Asiasat 2 will be 3-axis stabilized with an initial launch mass of 3.5 metric tons and will carry a payload of 24, 55-W, 6/4 GHz and 9, 115-W 14/12 GHz transponders (Figure 4.12). Asiasat 2 will be parked at 100.5° E, following an agreement with Thailand to avoid radio interference. Design studies are already underway for Asiasats 3 and 4 (References 79-82).

A late-arriving competitor to Asiasat is APT (Asia Pacific Telecommunications) Satellite Company, Ltd's APStar network. Underwritten primarily by Chinese corporations, APT Satellite Co. moved rapidly from its formation in 1992 to the launch of APStar 1 on 21 July 1994 by a Chinese CZ-3. The Hughes HS-376 spacecraft was outfitted with 24, low-power (16W) C-band transponders. To cover the East Asian region (PRC, Hong Kong, Japan, Singapore, Indonesia, and Vietnam), APStar 1 was to have been located at 131° E. However, concerns raised by Japan and Tonga about interference with spacecraft already in the 130-131° E area



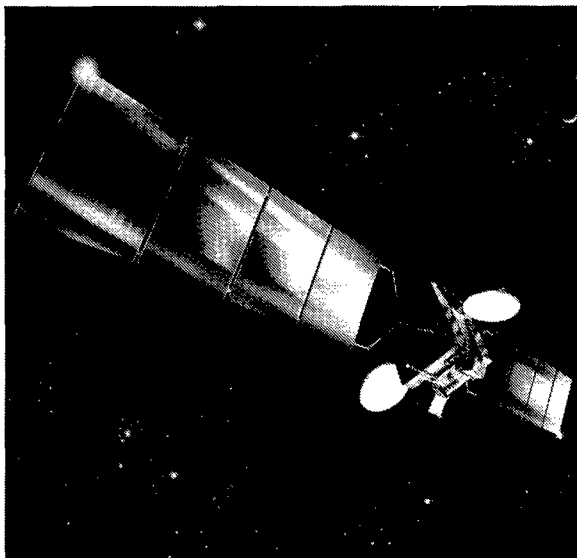


FIGURE 4.12 ASIAT 2 SPACECRAFT.

forced APStar to begin operations at  $138^{\circ}$  E under a lease arrangement with Tonga (References 83-88).

In late 1993 APT Satellite Co. signed a contract with Hughes to provide an HS-601 model spacecraft for launch as APStar 2 in 1994, although the launch was later delayed until early 1995. APStar 2 will carry a total of 34 transponders: 26 52-W C-band, 6 50-W Ku-band, and 2 120-W Ku-band (References 84 and 89).

#### 4.1.6 Hungary

During 1993-1994 Hungary and Israel discussed the feasibility of having an Israeli AMOS-class spacecraft serve as the first Hungarian GEO communications satellite. Named Magyarsat, the satellite would be co-located with AMOS 1 at  $4^{\circ}$  W, perhaps as early as 1998. A detailed agreement for full or partial use of the spacecraft telecommunications capacity was expected in 1995 (Reference 90).

#### 4.1.7 India

India first experimented with geosynchronous telecommunications relays in 1981 and now has three active spacecraft in GEO. Moreover, the launch of INSAT 2A in July, 1992, marked the debut of India's first domestically built operational GEO spacecraft. In a departure from most nations, India's GEO platforms combine a communications mission with that of Earth observation. By 1997 India's first commercial GEO communications network may also be operational.

India's first experimental GEO communications satellite, APPLE (Ariane Passenger Payload Experiment), was launched on the third test flight of the Ariane launch vehicle in June, 1981. For 27 months (until attitude control fuel depletion) the 350-kg Apple successfully served as a testbed for the entire Indian telecommunications space relay infrastructure despite the failure of one solar panel to deploy. The spacecraft bus was cylindrical with a diameter of 1.2 m and a height of 1.2 m. The communications payload consisted of two 6/4 GHz transponders connected to a 0.9 m diameter parabolic antenna.

Between 1982 and 1990 four U.S.-built INSAT 1 satellites were launched to support Indian domestic communications and Earth observation requirements as a joint venture among the Indian Department of Space, the Department of Telecommunications, the Meteorological Department, All-India Radio, and All-India Doorarshan Television. The Ford Aerospace spacecraft had a mass of 650 kg on station and carried twelve 6/4 GHz transponders with an output power of 4.5 W and three (two

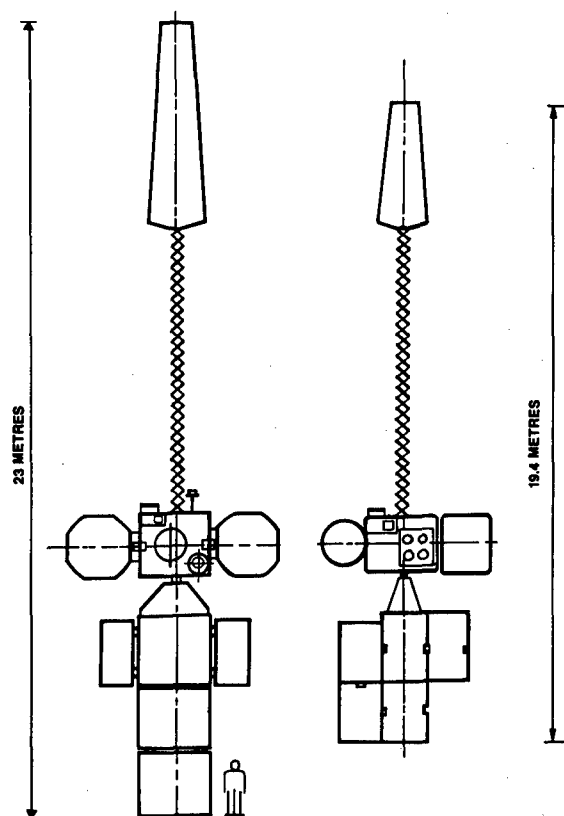


FIGURE 4.13 INSAT 2 (LEFT) AND INSAT 1 SPACECRAFT.

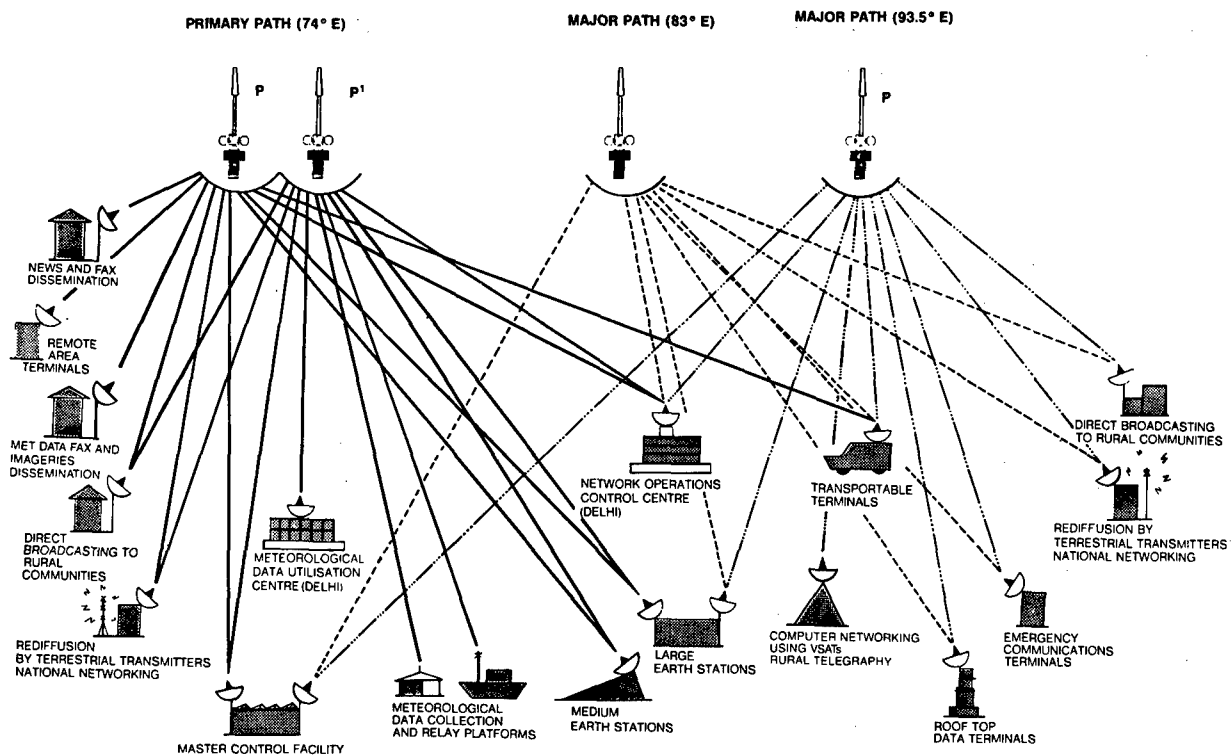


FIGURE 4.14 INSAT 2 SPACE SEGMENT CONCEPT.

active plus one backup) 6/2.5 GHz transponders. Both INSAT 1A (April, 1982) and INSAT 1C (July, 1988) were lost due to malfunctions within 18 months of launch. INSAT 1B (August, 1983) was no longer in operational service during 1993-1994, instead being used for special experiments. INSAT 1D (June, 1990) was operational at 83° E.

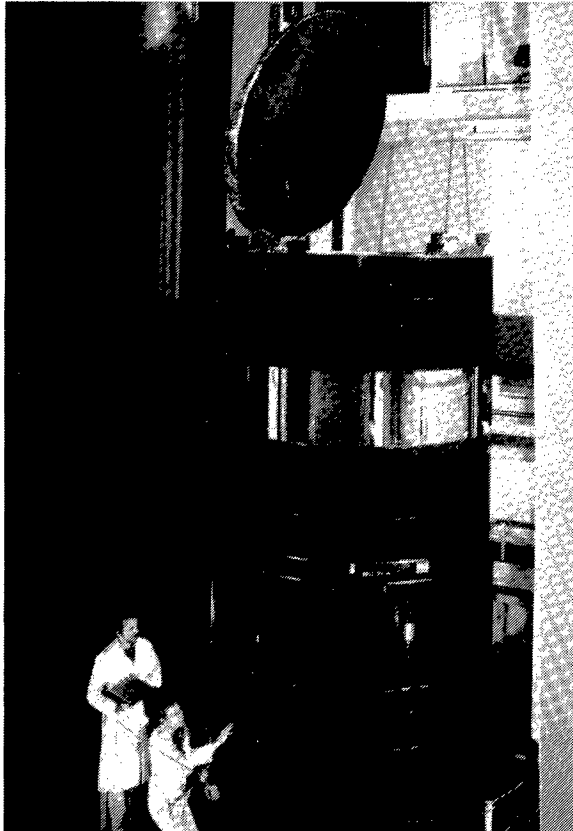
The INSAT 2 program was underway in 1983 to develop an indigenous multi-purpose GEO spacecraft that relied heavily on the previous Ford Aerospace design. In 1985 the basic spacecraft configuration was adopted, calling for an on-station dry mass of 860 kg which later rose to 910 kg (1,160 kg at beginning of life). The communications payload was increased with six additional 7/5 GHz transponders for a total of 18, plus two S-band transponders. The spacecraft bus is rectangular with side dimensions of 1.6 m by 1.7 m by 1.9 m (Figure 4.13). The asymmetric, accordion type solar panel produces 1.4 kW at beginning of life and is offset on the other side of the bus by an extendible solar sail (References 91-93).

INSAT 2A was finally launched on 9 July 1992 by an Ariane booster, about three years behind schedule. The spacecraft was positioned at the primary INSAT location of 74° E,

which was vacated by INSAT 1B in April, 1992. INSAT 2B was launched 22 July 1993 by an Ariane rocket and positioned at 93.5° E (Figure 4.14) (References 94-95).

In March, 1994, India selected Arianespace to launch INSATs 2C and 2D in 1995 and 1996, respectively. The spacecraft will be similar to the earlier INSATs but will be 200 kg heavier at launch (2,100 kg) and will carry larger solar arrays for 1.6 kW of electrical power. The communications payload will consist of 12 C-band, 6 extended C-band, 3 Ku-band, and 2 S-band transponders plus a new low-power C-band transponder for a mobile communications feeder. The design lifetime will be nine years. Preparations are also already underway for INSAT 2E, due to be launched in 1997, with special INTELSAT compatibility (References 96-99).

In late 1994, the relatively new Afro-Asian Satellite Communications (ASC) Ltd., headquartered in Bombay, was nearing the selection of a manufacturer for its 2-satellite GEO system. However, the purpose of the ASC network is to provide communications links to hand-held terminals, much like the proposed LEO cellular phone networks. The ASC service area will at first be concentrated in Central and Southern



**FIGURE 4.15 PALAPA B SPACECRAFT IN CHECKOUT.**

Asia with later expansion to other parts of Asia and Africa. The first launch could come as soon as late 1997 (References 100-102).

#### **4.1.8 Indonesia**

Since 1976 Indonesia has operated a national GEO telecommunications network based on U.S.-made Hughes, spin-stabilized spacecraft. Today the Palapa constellation consists of three HS-376 class spacecraft (Figure 4.15) located at 108° E (Palapa B2R, launched 13 April, 1990), 113° E (Palapa B2P, launched 29 March, 1987), and 118° E (Palapa B4, launched 14 May 1992). These second generation Palapa spacecraft have an on-station mass of 630 kg and have all been launched by Delta boosters. (Palapa B2R was originally launched as Palapa B2 by the U.S. Space Shuttle in February, 1984, but its perigee motor malfunctioned, leading to a Shuttle retrieval in November, 1984. The spacecraft was then refurbished and relaunched as Palapa B2R.).

The Palapa B series of satellites carry 30/4 GHz transponders (including six spares) to support telecommunications services through-

out Southeast Asia. The design lifetime of the spacecraft is eight years.

In 1991 the aging Palapa B1 satellite (June, 1983) was sold to Pasifik Satelit Nusantara (PSN) for a new mission to provide commercial services to the Pacific Rim region. Palapa B1 was moved to its new location near 134° E during March-May, 1992 and remained operational through 1994 despite its inclination of 4°. During 1993 PSN and Tonga clashed over the use of the 134° E slot before an acceptable solution was reached (References 103-107).

To handle the next generation of Palapa satellites, Palapa C, Indonesia in early 1993 established PT Satelit Palapa Indonesia (Satelindo) of Jakarta, a commercial firm with the PT Bimagraha Telekomindo the majority shareholder, to manage the Palapa C program and to secure additional investment funding. PSN is also assisting in the Palapa C program with communications services expertise. The first Palapa C spacecraft was originally scheduled for launch by an Ariane rocket in the Fall of 1995 to replace Palapa B2P (References 108-111).

The Palapa C series will employ Hughes' HS-601 spacecraft with 34 active transponders: 24 (with six spares) C-band, 6 (with two spares) extended C-band, and 4 (with two spares) Ku-band. The on-station mass of the satellite at beginning of life will be 1,775 kg with a design lifetime of at least 12 years. Palapa C1 will be followed in 1997-1998 by Palapa C2 which is designated to replace Palapa B2R.

On the horizon are two new GEO commercial communications networks with inaugural flights in 1996 and 1998, respectively. The Indostar system will provide direct broadcast television and radio services specifically for Indonesia. A Jakarta consortium, PT Media Citra plans to launch up to four American-built (International Technologies, Inc.'s Star spacecraft) satellites for positions at 105.9° E, 106.1° E, 114.9° E, and 115.1° E. The spacecraft will have an on-station mass of only 430 kg at the beginning of life with a design lifetime of at least seven years. The payload will consist of three S-band transmitters for television broadcasts and two L-band transmitters for radio services (References 112-113).

Trying to satisfy the growing demand for hand-held telephone service in Asia, PSN along with partners in Thailand and the Philippines plans to field the Asia Cellular Satellite System

(ACES), starting in 1998. The Garuda spacecraft will be built by Lockheed-Martin based on the A2100 satellite bus and will feature two 12-m umbrella antennas for L-band communications. PSN had earlier sought to create a cellular telephone system with Singapore (Section 4.1.24) but dropped out of the venture in 1994 (References 114-116).

#### 4.1.9 INMARSAT

The International Maritime Satellite Organization (INMARSAT) is the principal global provider of communications services to mobile (land, air, and sea) users. Based in London, INMARSAT was formed in 1979 and began operations in 1982 with leases of three American Marisat spacecraft launched in 1976. The organization continued to grow in 1993-1994, adding members ranging from the sultanate of Brunei Darussalam to Mexico to South Africa to the Bahamas. The last became the 74th member in mid-1994. In the mid-1980's INMARSAT expanded operations through ESA's MARECS spacecraft, which represented a specialized variation of the ECS/EUTELSAT satellites manufactured by the MESH consortium with British Aerospace as the prime contractor. The MARECS program evolved from the original Marots program (1973-1978) (Reference 7).

To replace the MARISAT and MARECS satellites, INMARSAT commissioned the development of the INMARSAT 2 series of spacecraft. Based on the Eurostar 1000 spacecraft bus created by British Aerospace and Matra Marconi, INMARSAT 2 satellites have an initial on-station mass of approximately 800 kg of which 130 kg is allocated to the payload. Electrical power capacity of the twin solar arrays (total span = 15.2 m) is 1.2 kW. Overall dimensions of the rectangular bus are 1.5 m by 1.6 m. The total communications package includes four active and two reserve 1.6/1.5 GHz transponders and one active and one reserve 6/4 GHz transponders.

The first two INMARSAT 2 spacecraft (Figure 4.16) were launched by American Deltas (October, 1990, and March, 1991). INMARSATs 2 F3 and 2 F4 followed on 16 December 1991 and 15 April 1992 via Ariane launch vehicles. At the beginning of 1995, these four spacecraft were serving as the primary nodes in the INMARSAT network at 64.5° E (2 F1), 178° E (2 F3), 344.5° E (2 F2), and 305° E (2 F4). Selected INTELSAT and MARISAT satellites

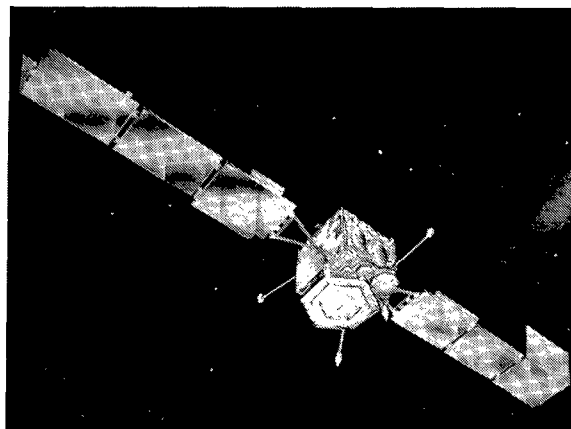


FIGURE 4.16 INMARSAT 2 SPACECRAFT.

are also employed as needed in the INMARSAT network.

The third generation INMARSAT satellites are currently being manufactured by a team led by Matra Marconi (payload) and Lockheed-Martin (spacecraft, Satcom 4000 bus). Five of the 1.1 metric ton (on-station) spacecraft are tentatively scheduled (after repeated delays) for launch in 1995-1997: the first two by Atlas, the third and fifth by Ariane, the fourth by Proton. The approximately 200 kg payload will retain the same 1.6/1.5 GHz and 6/4 GHz communications links and will add a navigation package. Design lifetime will be 13 years for INMARSAT 3 compared to 10 years for INMARSAT 2 (References 117-121).

During 1993-1994 INMARSAT was beset with pressures to privatize and to select a new satellite constellation to service the growing demand for hand-held telephone communications. From the Project 21 study in early 1993 with three design concepts, INMARSAT selected a medium-altitude network for its proposed INMARSAT-P system. Twelve, Hughes-built, 2.5-metric-ton spacecraft will be deployed at altitudes near 10,000 km with inclinations of 55°. The first launch could come as early as 1998, leading to some network services by 1999 (References 122-133).

#### 4.1.10 INTELSAT

The International Telecommunications Satellite Organization (INTELSAT) marked its 30th anniversary in August, 1994, as the premier provider of satellite-based communications in the world. From an initial 14 countries, INTELSAT grew to 134 member nations by 22 August 1994 (two days after its 30th anniversary) with

the Republic of Kazakhstan being the most recent addition.

During 1965-1994 a total of 51 INTELSAT satellites were launched, of which 42 successfully reached GEO and operational status. These spacecraft varied in on-orbit mass from 38.5 kg to 1,896 kg and constituted ten generations: INTELSAT 1: 1, INTELSAT 2: 4, INTELSAT 3: 8, INTELSAT 4: 8, INTELSAT 4A: 6, INTELSAT 5: 9, INTELSAT 5A: 6, INTELSAT 6: 5, INTELSAT K: 1, and INTELSAT 7: 3. As of 1 January 1995, INTELSAT was operating 21 spacecraft of five principal families at 20 GEO locations around the world.

The oldest operational INTELSAT series with seven active spacecraft is the INTELSAT 5, produced by Ford Aerospace with MBB and Aerospaziale as major sub-contractors. Each INTELSAT 5 spacecraft (launched between 1980 and 1984) is 3-axis stabilized (the first such use by INTELSAT) with an initial on-station mass of approximately 1,000 kg and a payload of 21 C-band transponders and six Ku-band transponders. The INTELSAT 5A series (launched between 1985 and 1989) added 11 additional C-band transponders and about 175 kg of mass. All five INTELSAT 5A spacecraft successfully deployed in GEO were still operational at the end of 1994. Beginning with INTELSAT 505 (aka INTELSAT 5 F5), most INTELSAT spacecraft have carried additional INMARSAT-compatible C-band and L-band transponders.

In 1989 the INTELSAT 6 series, produced by Hughes with major assistance from British Aerospace, MBB, Alenia Spazio, and Alcatel Espace, debuted as the largest INTELSAT satellite to date. With a 1.9 metric ton on-station mass, each INTELSAT 6 satellite carries 38 C-band transponders and 8 Ku-band transponders. All five INTELSAT 6 were successfully deployed in GEO (although INTELSAT 6 F3 had to be rescued by the US Space Shuttle and then sent on its way after an initial launch malfunction) during 1989-1991 and remain operational.

The solitary INTELSAT K spacecraft, launched in 1992, was designated to become GE Americom Satcom K4 but became available in 1989 when the original owners abandoned a proposed project. The GE 5000 series satellite had a 1,550-kg beginning-of-life on-station mass with a 10-year design lifetime. The payload consisted of 16 moderate-power (62.5 W) Ku-band transponders. INTELSAT K is co-

located with INTELSAT 512 (aka INTELSAT 5/5A F12) at 21.5° W.

Deployment of the first three INTELSAT 7 spacecraft was performed during 1993-1994. INTELSATs 701 and 702 were launched by Ariane rockets on 22 October 1993 and 17 June 1994, whereas INTELSAT 703 was lifted by an Atlas 2AS. INTELSAT 7 is based on a Loral FS-1300 bus with the primary payload furnished by Alcatel Espace. The spacecraft has an on-station mass of about 1.8 metric tons and a design lifetime of 11 years or more. The payload includes 26 C-band and 10 Ku-band transponders. Six additional INTELSAT spacecraft were scheduled for launch during 1994-1995, as well as two INTELSAT 7A satellites. The latter will be virtually identical to their predecessors but will carry higher power Ku-band transponders.

The next generation INTELSAT spacecraft, the INTELSAT 8/8A series, will begin launches in 1996 with as many as six deployed by the end of 1997. The Lockheed-Martin series 7000 spacecraft will have a design lifetime of at least 14 years (Reference 134).

#### **4.1.11 Iran**

Since the 1970's Iran has considered establishing a GEO communications satellite network. After several abortive attempts, Iran reached a tentative agreement in 1993 to purchase a pair of western satellites for its Zohreh system. With spacecraft stationed at 26° E and 34° E, the Zohreh system will provide both L-band (INMARSAT-compatible) and Ku-band (14 transponders) links. The 1,850-kg spacecraft are to be furnished by Alcatel Espace and Aerospaziale with design lifetimes of 10 years. In the meantime, Iran is leasing Ku-band capacity on INTELSAT spacecraft (References 135-137).

#### **4.1.12 Israel**

Although by the end of 1994 Israel had launched only two small experimental LEO satellites, the country was preparing to launch its first GEO spacecraft in 1995 on board an Ariane vehicle. Developed by Israel Aircraft Industries with assistance from DASA and Alcatel Espace, the 500-kg-class AMOS (Affordable Modular Optimized Satellite) will carry 7 Ku-band transponders (plus two spares) for Eurasian communications services.

AMOS is a 3-axis-stabilized satellite with a mostly rectangular spacecraft bus (2m x 2m x 1.5m) and two short solar arrays providing

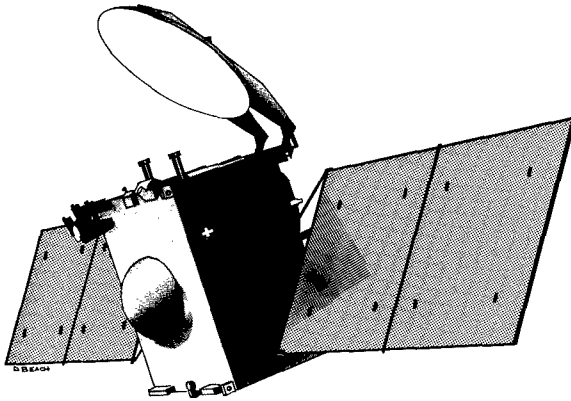


FIGURE 4.17 AMOS SPACECRAFT.

about 1 kW of electrical power. An operational lifetime of up to 10 years is expected for AMOS 1 at a location of  $4^{\circ}$  W. AMOS 1 will be tested in a simulated space environment by INTESPACE (France) in 1995. An AMOS-class satellite is also being considered by Hungary for its Magyarsat system (Section 4.1.6). The Hungarian satellite would also be located at  $4^{\circ}$  W and could serve as a backup to AMOS 1 (References 138-146).

A LEO microsat named Techsat 1 (aka Gurwin 1) was in final preparation in late 1994 for an early 1995 piggy-back launch on the maiden flight of the Russian Start launch vehicle. Developed at the Asher Space Research Institute of the Israel Institute of Technology with the assistance of the Israel Space Agency and IAI, Techsat 1 is a 3-axis-stabilized spacecraft of 50 kg mass. The multi-purpose payload will include a digital store/dump message handling system for amateur radio operators as well as a UV telescope, a CCD imaging system, and X-ray detectors. The spacecraft is to be inserted into an orbit of approximately 700 km altitude (References 144-145, 147-148).

#### 4.1.13 Italy

Italy began its national space-based telecommunications program with the experimental Sirio spacecraft developed in the 1970's. These relatively small (approximately 220 kg on-station in GEO), spin-stabilized spacecraft were constructed by an Italian aerospace consortium to test the characteristics of 18/12 GHz transmissions. The drum-shaped spacecraft had a diameter of 1.4 m and a height of 1 m and was covered with solar cells which produced a maximum of 150 W. Sirio 1 was launched in 1977

and functioned well past its 2-year design life before being retired in 1992. Sirio 2 was lost in an Ariane launch failure in 1982.

Italy's first operational communications satellite was launched 15 January 1991 by an Ariane booster. Developed by a contractor team led by Alenia Spazio, ITALSAT carries ten active transponders plus five spares for 30/20 GHz and 50/40 GHz links with a capacity of 12,000 telephone circuits. The 900-kg (on-station) spacecraft consists of a rectangular bus 2.3 m by 2.7 m by 3.5 m and two solar panels with a total span of 21.8 m and more than 1.5 kW power. The design life for the first test vehicle is only five years. ITALSAT 2 is not scheduled for launch until 1996 when it will also carry ESA's first European Mobile Services payload. ITALSAT 2 was undergoing environmental testing in France in late 1994. ITALSAT 1 is stationed at  $13.2^{\circ}$  E, which will also be the home of ITALSAT 2 (References 146, 149-152).

Two new GEO systems are under consideration by Italy for deployment by the end of the decade. SARIT (Satellite di Radiodiffusione Italiana) could provide direct broadcast television service formerly handled by ESA's Olympus Satellite and may be based on the ITALSAT design. This ambitious project is currently suffering from the organizational and budgetary difficulties at ASI. Also being designed is the SICRAL (Sistema Italiana de Comunicazione Riservante Allarmi) military communications system with satellites positioned at  $16^{\circ}$  and  $22^{\circ}$  E. The multi-purpose spacecraft would include transponders for 8/7 GHz and 14/11 GHz communications. Alternatively, SICRAL may appear as a transponder package on another host spacecraft. In either case, launch is not expected until 1997 or later.

Meanwhile, in LEO two Italian microsatellites were launched in 1993 less than a month apart. The first, TEMISAT (Telespazio Micro Satellite), was built by Germany's Kayser-Threde GmbH under contract to Italy's Telespazio and was launched as a piggy-back satellite with Russia's Meteor 2-21 on a Ukrainian Tsyklon launch vehicle. The 32-kg TEMISAT was released into an orbit of 937 km by 969 km at an  $82.5^{\circ}$  inclination on 31 August 1993. The principal mission of TEMISAT is to collect environmental data from numerous, dispersed transmitters and forward the information to special data collection centers in the 138-150 MHz band. TEMISAT 1 was expected to oper-

ate 3-5 years but failed in the Fall of 1994 (References 153-157).

ITAMSAT (Italian Amateur Satellite), aka OSCAR 26, was launched as one of six piggy-back microsattellites on the SPOT 3 mission on 26 September 1993. From its 500-km sun-synchronous orbit, ITAMSAT, like its amateur radio satellite predecessors, will connect radio enthusiasts around the world. The 10-kg, 23-cm cube satellite was designed and built by the Associazione Radiomatori Italiani near Milan for only \$200,000. A second ITAMSAT is under development (References 158-160).

#### 4.1.14 Japan

By the end of 1994 Japan had deployed 19 GEO communications satellites from five series and was maintaining a constellation of 10 operational satellites at seven locations in the geostationary ring from 110° E to 162° E. Japan's extensive satellite-based communications program is 17 years old and has been promoted by both the national space agency NASDA and by the commercial sector. Since the program's inception, Japan has employed a mix of domestic and foreign spacecraft and launch services. Although Japan deployed another commercial communications satellite during 1993-1994, the long-awaited experimental ETS VI failed to reach GEO and was stranded in GTO.

Japan's Engineering Test Satellite (ETS) series began in 1975, and two years later NASDA's first GEO platform ETS II (also known as Kiku-2) was launched by an N-I booster and stationed at 130° E. This mission not only validated the GEO launch technique but also tested spacecraft control systems vital to future communications satellites. Experimental communications at 1.7 GHz, 11.5 GHz, and 34.5 GHz were tested. The 130-kg, spin-stabilized ETS II was finally retired in 1991.

The first ETS series spacecraft to have a specific communications objective was ETS V (Kiku-5), launched on 27 August 1987 by an H-I booster and stationed at 150° E. ETS V was Japan's first 3-axis stabilized GEO satellite with an on-station mass of 550 kg. The spacecraft carried two 1.6/1.5 GHz transponders to test an INMARSAT compatible mobile communications system. The spacecraft bus measured 1.4 m by 1.7 m with a twin solar panel span of 9.7 m. At the end of 1994, ETS V was still positioned near 150° E.

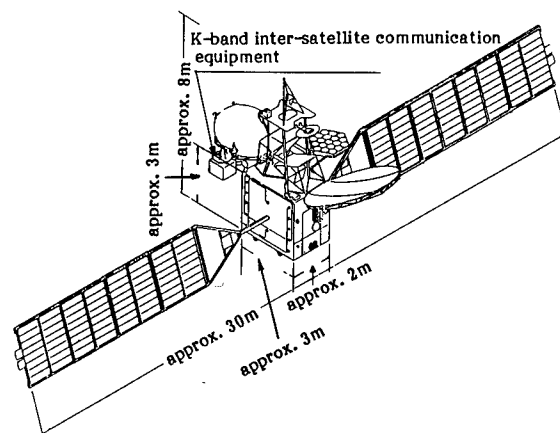


FIGURE 4.18 ETS VI SPACECRAFT.

ETS VI, with a wide assortment of communications systems and experiments, was launched on the second mission of the new H-II vehicle on 28 August 1994. Although the H-II performed as expected and placed the spacecraft into a GTO, the Liquid Apogee Propulsion System (LAPS) malfunctioned, leaving ETS VI in an elliptical orbit of approximately 7,800 km by 38,700 km at an inclination of 13.1°. The spacecraft remained operational, but its non-nominal orbit posed severe experimental limitations and presented unanticipated environmental stresses.

The 2.0-metric-ton (on-station) ETS VI was designed and manufactured by prime contractors Toshiba and Mitsubishi. The spacecraft bus is 2m x 2.8m x 3m and supports two solar arrays (total power = 4.2 kW) with a span of approximately 30 m (Figure 4.18). The 660-kg payload includes numerous transponder systems, primarily at the higher frequencies of 30/20 GHz and above. A major mission objective was the testing of an inter-satellite communications system utilizing Ka-band, S-band and O-band links. A laser space-ground link was also planned, as were tests of a new ion propulsion system. The design 10-year lifetime will probably not be met, but most of the experiments are expected to be carried out, if not as extensively as planned (References 161-170).

Prior to the ETS VI failure, the next communications-oriented ETS mission was the proposed ETS N which would be launched about 2001 to test cellular phone technologies. Also under consideration is an ETS VIII which could

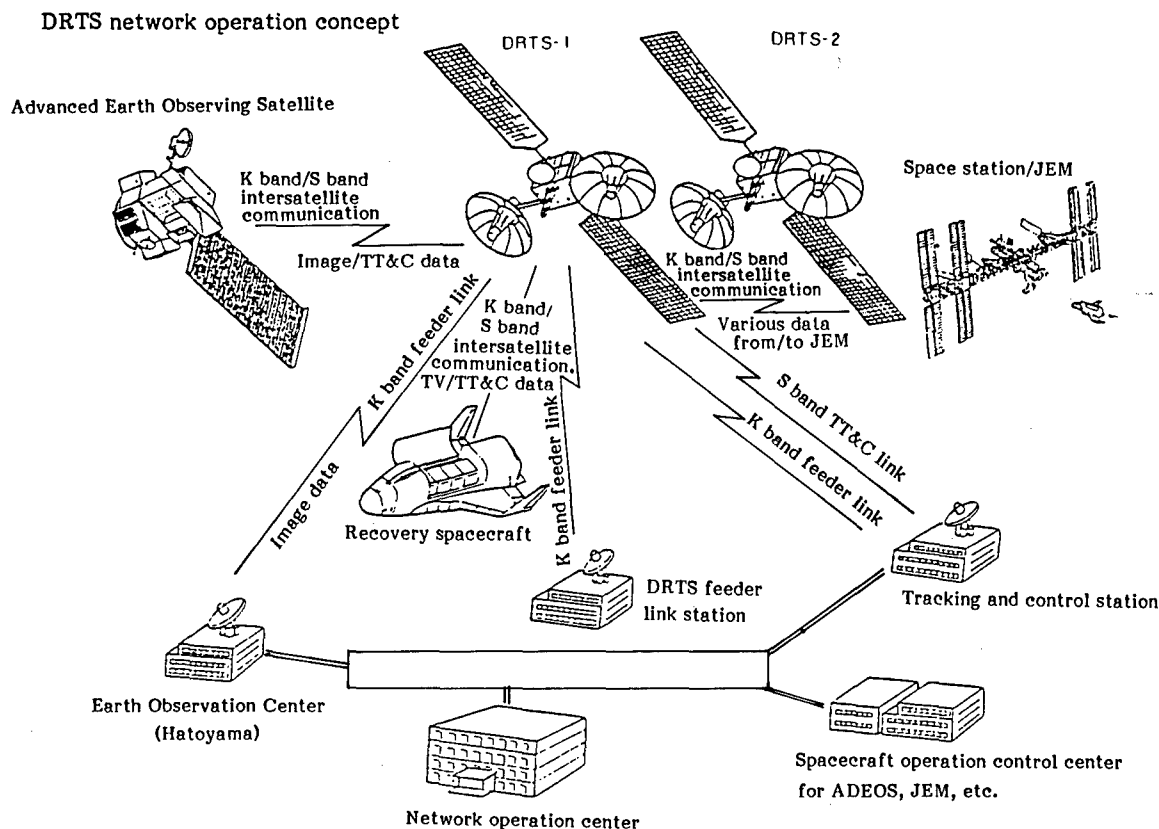


FIGURE 4.19 DRTS NETWORK OPERATION CONCEPT.

combine the objectives of ETS VI and N (References 171-172).

Already in development before the ETS VI accident was the Communications and Broadcasting Engineering Test Satellite (COMETS), also sponsored by NASDA, designed to test inter-satellite and advanced mobile satellite communications. With an overall mass and spacecraft bus similar to ETS VI, COMETS, to be launched in 1997, would carry a variety of Ka-band and S-band transponders and would be stationed at 121° E. Gallium arsenide solar cells will provide increased power (up to 5.5 kW) as compared to ETS VI. Eventually a 2-satellite Data Relay and Tracking Satellite (DRTS) network (Figure 4.19) is envisioned with full compatibility with its American and European counterparts (References 173-177).

A LEO laser-based optical communications testbed has been approved by NASDA for launch in 1997 on a J-I booster. Dubbed OICETS (Optical Inter-Orbit Communications Engineering Test Satellite), the 500-kg class vehicle will be placed into a 500-km-high orbit and will work directly with ESA's ARTEMIS satellite. OICETS will carry both S-band and laser

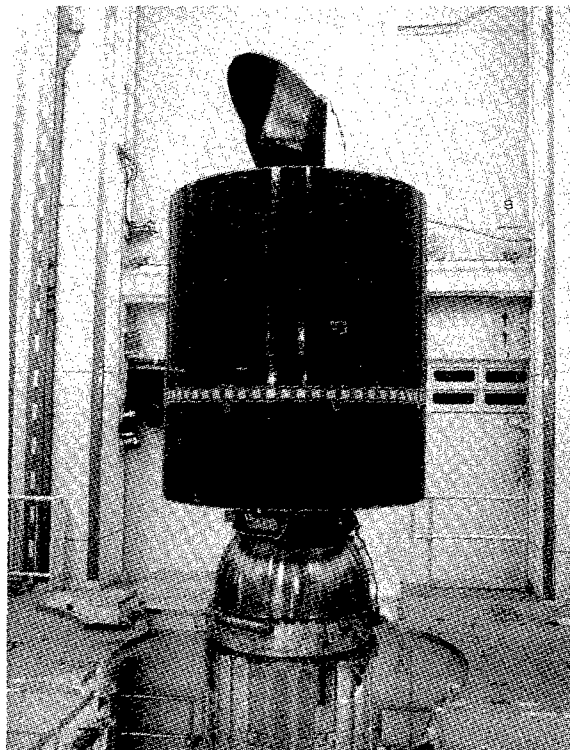


FIGURE 4.20 CS-3A SPACECRAFT.



communications packages. The rectangular spacecraft bus will be approximately 0.8m x 1.1m x 1.5m with two solar arrays stretching a total span of nearly nine meters (References 178-181).

The Japanese CS (Communications Satellite) series has been highly successful since its debut in 1977. The prototype satellite CS (also known as Sakura) was operational from 1977 to 1985. The second generation, operational spacecraft, CS-2a and CS-2b, were launched in 1983 and continued to function until 1991 and 1990, respectively.

The current constellation is comprised of CS-3a and CS-3b (launched in 1988) and stationed at 132° E and 136° E. These spin-stabilized, drum-shaped (diameter of 0.2 m and height of 0.3 m) spacecraft (Figure 4.20) possess an on-orbit mass of 550 kg (compared to the 350 kg CS-2 satellites) and are based on U.S. Ford Aerospace designs. The communications payload consists of 10 active plus five spare 30/20 GHz transponders and two active plus one spare 6/4 GHz transponders. The primary contractors are Mitsubishi and NEC Corporation (References 175 and 182).

By the time the design lives of CS-3a and CS-3b are reached in 1995, the next generation of satellites in the series are scheduled to be launched. Known as CS-4 or N-Star, the new spacecraft will be procured by the Nikon Telegraph and Telephone company from the U.S. and will be based on Loral's FS-1300 platform. The N-Star payload will consist of eight 14/11 GHz, eleven 30/20 GHz, and five 6/4 GHz transponders and should be operational for ten years. Aerospatiale is under contract to provide unique 2.6 m by 4.5 m composite antennas for the C-band and Ku-band transponders. The N-Star spacecraft may also be able to satisfy some of the objectives of the hampered ETS VI (References 175, 183-185).

A year after the first CS-class satellites were launched, the BS (Broadcasting Satellite) program was inaugurated with the flight of BSE (Experimental) also known as Yuri. As the name implies, BS satellites are designed for television broadcasting and were initially developed for the Japanese Ministry of Posts and Telecommunications and for the Japan Broadcasting Corporation (NHK). All BS satellites have been located at 110° E and have been of the same basic configuration: 3-axis stabilization of a

rectangular spacecraft bus with two elongated solar arrays.

The 350-kg BSE was followed in 1984 and 1986 by the operational and essentially identical BS-2a and BS-2b, respectively. Each spacecraft carried two active and one spare 100 W, 14/12 GHz transponders. Built by Toshiba with assistance from General Electric, the BS-2 series were designed for five years of operations. BS-2a was moved to a graveyard orbit in 1989, followed by BS-2b in 1992.

After losing two BS spacecraft in launch accidents (Ariane in February, 1990, and Atlas-Centaur in April, 1991), the BS constellation from 1990-1994 consisted of BS-3a (August, 1990) and BS-3b (August, 1991). The BS-3 class satellites (Figure 4.21), which have experienced some difficulties, have an initial on-station mass of 550 kg and are based on the Lockheed-Martin (GE) 3000 bus. The 15-m span solar arrays provide slightly less than 1.5 kW at beginning of life. The payload includes three active and three backup 14/12 GHz transponders and a single 14/13 GHz unit. A third BS-3 named BS-3N was finally launched by Ariane on 8 July 1994. Co-located with its predecessors and with a similar payload, the spacecraft possessed a higher on-station mass of 700 kg. A more powerful B-SAT (formerly BS-4) generation spacecraft is under development for a maiden launch in 1997. The Hughes-built, 1.25-metric-ton spacecraft are being developed by the newly formed B-SAT (Broadcast Satellite

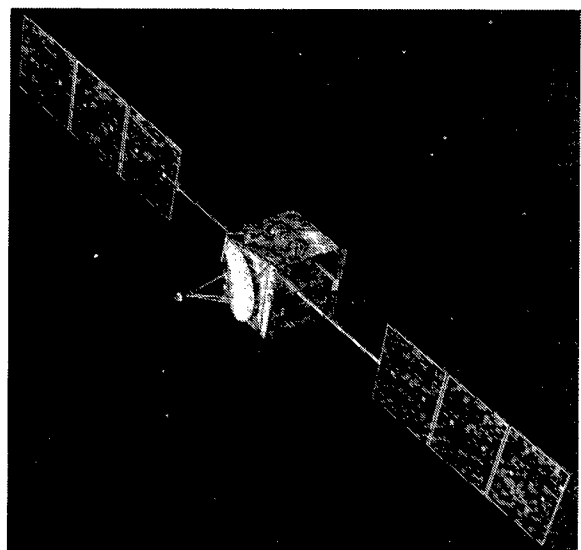


FIGURE 4.21 BS-3 SPACECRAFT.

System) Corporation (References 175, 186-194).

During 1979-1980 Japan launched two Experimental Communications Satellites (ECS, also known as Ayame) on N-I boosters from Tanegashima. However, both satellites were lost shortly after launch during the firing of their apogee kick motors. These small, 130-kg, spin-stabilized satellites were not replaced and the Japanese ECS program was terminated.

In 1989 two, purely commercial Japanese communications networks were started, both relying on U.S.-made spacecraft. In 1985 the Japanese Communications Satellite Company was created by Hughes, Mitsui, and C Itoh as a commercial alternative to the Government controlled CS and BS satellites for the full range of telecommunications services (Hughes later left the consortium). In March, 1989, and January, 1990, JCSAT 1 and JCSAT 2 were launched by Ariane and Titan 3 boosters, respectively. Both spacecraft are identical and based on the Hughes HS-393 platform.

These 1.4-metric-ton spin-stabilized spacecraft are 3.7 m in diameter and 10 m tall when the solar array skirt is extended. The communications payload consists of 40 14/12 GHz transponders (including eight spares), working through a single 2.4 m diameter antenna. The JCSAT spacecraft are deployed at 150° E (next to ETS V) and 154° E and are designed to operate for at least ten years. JCSAT 3 was scheduled for launch in 1995 and will use the larger HS-601 bus to carry 12 C-band and 28 Ku-band transponders. The on-station mass will be 1,820 kg (References 195-200).

The Space Communications Corporation of Japan (SCC) was formed a month before

JCSAT in 1985 but did not launch its first satellite until three months after its competitor. SCC's Superbird spacecraft are based on Loral's (formerly Ford Aerospace) FS-1300 bus, which was also selected for the N-Star replacement of the CS-3 satellites. The 1.5-metric-ton Superbird spacecraft carry a total of 26 transponders: 23 (with 8 spares) at 14/12 GHz and 3 at 29/19 GHz.

Superbird A was launched in June, 1989, by Ariane (as have been all Superbird satellites) and was stationed at 158° E. A second satellite, Superbird B, was lost in the Ariane accident of February, 1990. Before a replacement could be launched, Superbird A malfunctioned, necessitating its transfer to a graveyard orbit in 1991. The constellation of two spacecraft (Figure 4.22) at 158° E and 162° E was finally established in 1992 with Superbird A1 (1 December 1992) and Superbird B1 (26 February 1992). Both were still operational at the end of 1994. Superbird C, based on the Hughes HS-601 platform, will be launched in 1997 with a total of 24 C-band and Ku-band transponders (References 201-204).

In 1986 and then again in 1990 Japan launched small amateur radio satellites under the OSCAR program. The two 50-kg spacecraft, Fuji 1 (Oscar 12) and Fuji 2 (Oscar 20), were constructed by the Japan Amateur Radio League and were roughly 0.4 m by 0.4 m by 0.5 m. Fuji 1 was inserted into a nearly circular orbit of about 1,500 km at an inclination of 50° along with a primary geodetic payload, and Fuji 2 accompanied a maritime observation satellite into space, reaching an orbit of 910 km by 1,750 km at an inclination of 99°. Fuji 1 failed in 1989, but Fuji 2 remained operational in 1994.

#### 4.1.15 Luxembourg

The Luxembourg-based Societe Europeenne des Satellites (SES) provides telecommunications services to most of Europe via American-manufactured spacecraft. The Astra network was doubled during 1993-1994 and at the end of 1994 consisted of four satellites, all launched by Ariane and stationed at 19.2° E: Astra 1A (December, 1988), Astra 1B (March, 1991), Astra 1C (May, 1993), and Astra 1D (November, 1994).

Astra 1A and Astra 1B are both based on Lockheed-Martin (GE Astro Space) spacecraft buses, although the former is a 1.0 metric ton 4000 series platform and the latter is a 1.5 met-

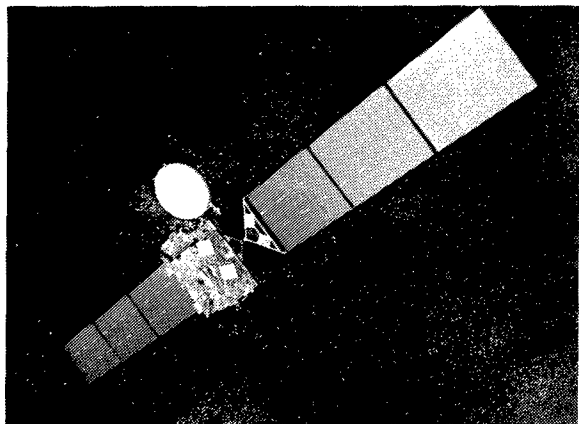


FIGURE 4.22 SUPERBIRD SPACECRAFT.

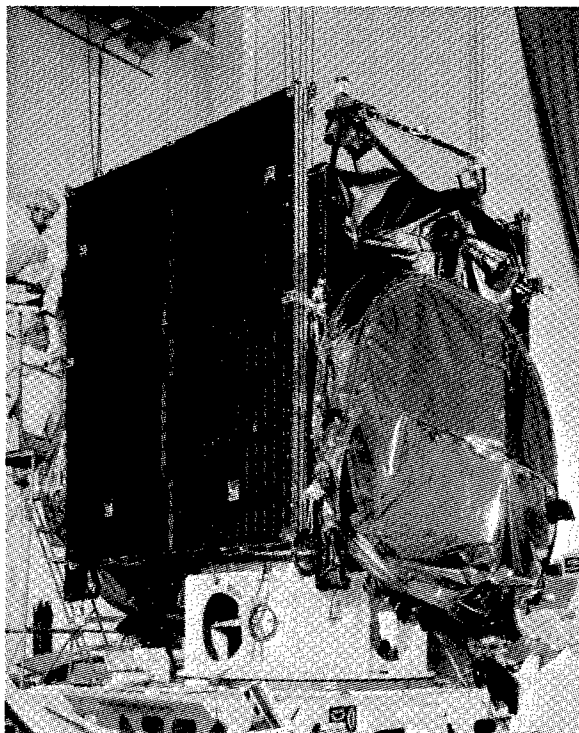


FIGURE 4.23 ASTRA 1C SPACECRAFT IN CHECKOUT.

ric ton 5000 series platform. Astra 1A measures 1.5 m by 1.7 m by 2.1 m with a solar panel span of 19.3 m and 2.8 kW capacity. Meanwhile, Astra 1B has overall dimensions of 2.2 m by 2.2 m by 2.8 m with a solar panel span of 24.3 m and 4.9 kW. Both spacecraft carry 16 Ku-band transponders, but those on Astra 1B are higher power (60W versus 45W).

Astra 1C and 1D rely on the Hughes HS-601 spacecraft bus with an on-station mass of 1.7 metric tons. Each spacecraft carries 16 Ku-band transponders (plus six spares) and spans 21m across its two solar arrays, which provide more than 3 kW. The design lifetime is at least 15 years.

Four additional Astra 1 spacecraft are scheduled for launch during 1995-1998 and all will be procured from Hughes. Astra 1F in 1996 will become the first Western GEO communications satellite to be launched by Russia's Proton booster (References 205-209).

#### 4.1.16 Malaysia

A long-time user of INTELSAT and Indonesian communications satellites, Malaysia decided in 1991 to establish a domestic GEO communications system with the aid of US-built spacecraft. Two Malaysia East Asia Satellites

(MEASATs) are scheduled for launch beginning in 1996 with a principal location at 91.5° E. The Hughes HS-376 spin-stabilized spacecraft will feature several improvements over its class, including gallium arsenide solar cells, greater payload power availability, and a new lightweight, high-gain antenna. The MEASAT 1 communications payload will consist of 12 C-band and four, high power (110 W) Ku-band active transponders. The design lifetime is 12 years (References 210-215).

#### 4.1.17 North Atlantic Treaty Organization (NATO)

Headquartered in Brussels, Belgium, the NATO Communications and Information Systems Agency maintains three primary operational spacecraft in GEO to provide command, control, and communications among the US and the European members of NATO. The NATO Phase I communications network used the US Defense Satellite Communications System (DSCS) from 1967 until Phase II began with the launches of NATO 2A and NATO 2B in March, 1970, and February, 1971. These spacecraft were based on the UK Skynet 1 design with an on-station mass of 130 kg and X-band transponders.

The NATO 3 series included four spacecraft deployed between 1976 and 1984: NATO 3A (April, 1976), NATO 3B (January, 1977), NATO 3C (November, 1978), and NATO 3D (November, 1984). Produced by Ford Aerospace, the spin-stabilized NATO 3 spacecraft possessed an on-station mass of 310 kg and retained similar X-band frequencies. At the start of 1993, NATO 3B and 3D were both still operational, although the former was retired and placed in a graveyard orbit in July of that year. NATO 3D remained on station through 1994 at 21° W.

In 1991 the NATO 4 series, based on the UK's Skynet 4 spacecraft, debuted with the launch of NATO 4A in January. NATO 4B followed in December, 1993, and together the two satellites serve as the backbone of NATO's satellite communications system. They are deployed at 18° W and 6° E, respectively, with an on-station mass of more than 800 kg and a design lifetime of seven years. The communications bands are now in the UHF (2 transponders) and SHF (3 transponders) bands. Plans for a NATO 5 series are likely to be shelved in favor of leasing commercial circuits (References 216-218).

#### 4.1.18 Norway

Norway became an instant GEO communications operator when in late 1992 Norwegian Telecom purchased the on-orbit Marcopolo 2 (aka BSB R2) spacecraft from the firm of British Satellite Broadcasting. Marcopolo 2 is a Hughes HS-376 class spacecraft launched in August, 1990. The spin-stabilized spacecraft (2.2 m diameter and a deployed height of 7.2 m) had an initial on-station mass of 660 kg and a payload of five active Ku-band transponders. The spacecraft, renamed Thor, was moved from 31° W to 1° W, where it remained in operation throughout 1993-1994. Thor is being aided by INTELSAT 702, which is co-located with Thor (References 219-220).

#### 4.1.19 Pakistan

Although Pakistan has expressed an interest to develop a GEO communications system, the country is still several years away from deploying the first satellite. In the meantime, Pakistan is experimenting with basic store/dump communications relays in LEO. A 50-kg Badr-1 satellite was launched as a secondary payload on the Chinese CZ-2E mission of 16 July 1990. Originally designed for a nearly circular orbit of 400-500 km, Badr-1 was inserted into an orbit of 205 km by 990 km which led to a natural decay after only 145 days, although contact with the vehicle ceased on 20 August. However, during its short mission, the satellite successfully completed store/dump message tests using 144-146 and 435-436 MHz frequencies.

The Pakistan GEO constellation is being designed with a capacity of 4,800 long distance telephone channels, 2,400 rural circuits, and two direct broadcast television channels in the 14/11 GHz band. PAKSAT GEO locations near 38° E and 41° E are planned (References 221-222).

#### 4.1.20 People's Republic of China

The PRC currently operates a constellation of three Dongfanghong-2 (DFH-2) communications satellites in GEO for domestic needs. The debut of the much more capable DFH-3 series was spoiled in late 1994 when the spacecraft failed to reach GEO. Meanwhile, a second-hand US satellite has been procured and new satellite designs are in development.

Designed, manufactured, and launched by indigenous means, the modest DFH-2 space-

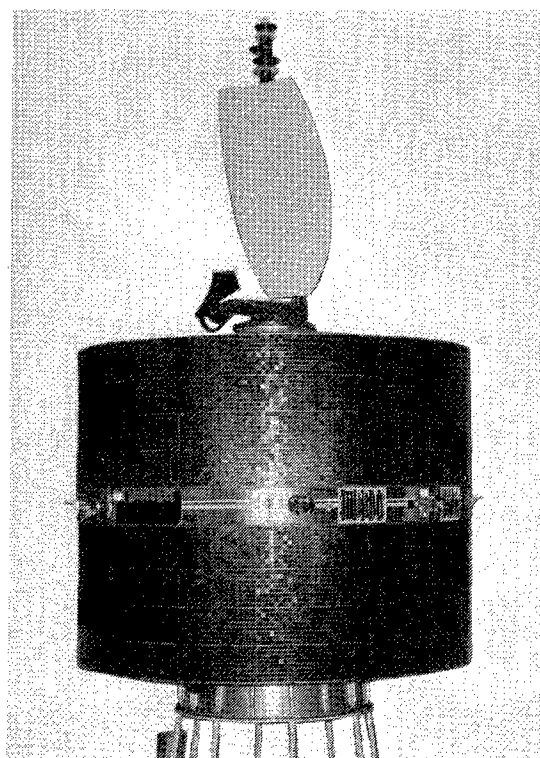


FIGURE 4.24 DFH-2 SPACECRAFT.

craft are analogous to 1960's era Western GEO satellites (e.g., INTELSAT 3), although slightly heavier. After an initial CZ-3 launch failure in January, 1984, the first Chinese GEO satellites were deployed in April, 1984, and February, 1986, to 125° E and 103° E, respectively. Both satellites apparently continued to operate until 1990-1991, by which time they had been replaced by the operational DFH-2 series. With an on-orbit mass of 441 kg (compared to 433 kg for the earlier satellites), DFH-2 spacecraft were successfully placed in GEO in March, 1988, December, 1988, and February, 1990, and positioned at 87.5° E, 110.5° E, and 98° E, respectively. All three satellites remained on station at the end of 1994. A fourth DFH-2 was lost on 28 December 1991 when its CZ-3 upper stage failed to reignite.

The DFH-2 is a spin-stabilized, drum-shaped satellite with a diameter of 2.1 m and a height of 3.1 m (Figure 4.24). The communications payload consists of only two 6/4 GHz transponders with an output power of 10 W. The total electrical power capacity is assessed to be about 300 W (the first two experimental satellites were rated at 284 W) (References 223-227).

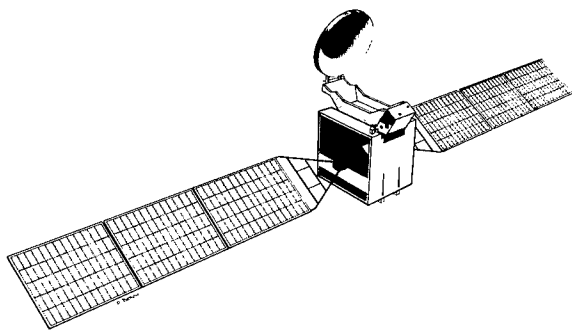


FIGURE 4.25 DFH-3 SPACECRAFT.

The DFH-3 generation spacecraft, long in development, will be much larger (more than one metric ton on-station), will utilize 3-axis stabilization, and will bear a resemblance to the GE Astro Space 5000 series spacecraft (Figure 4.25). More importantly, the communications payload will consist of up to 24 6/4 GHz transponders for both telephone and television transmissions. The design life of the DFH-3 will be double that of DHF-2, i.e., eight years compared to four years.

Due to its size the DFH-3 requires a more capable launch vehicle than the DFH-2's CZ-3. To this end the CZ-3A was first tested on 8 February 1994, successfully placing a dummy DFH-3 spacecraft and a small scientific satellite into GTO. Nearly 10 months later on 29 November, DFH-3 1 followed, entering GTO precisely as planned. Unfortunately, however, the German-supplied apogee kick stage malfunctioned, causing Chinese officials to use the spacecraft's propulsion system to lift the vehicle into a sub-geosynchronous orbit where the spacecraft was declared lost. (DASA also contributed components for the communications antennas and solar array mechanism as well as provide overall design guidance.) The second DFH-3 spacecraft was not expected to be ready for launch until 1996 (References 228-238).

During 1993-1994 DASA and China formed a new venture named EuraSpace which will develop a follow-on DFH-3 spacecraft designated Sinosat. Like DFH-3, Sinosat will be largely Chinese made with some German components and management assistance. The preliminary design for Sinosat envisions as many as 12 C-band and six Ku-band transponders initially with growth up to 30 transponders. The spacecraft is likely to be 50% more massive than DFH-3, but the first launch will probably

not occur before 1997 (References 236, 239-243).

To help offset the loss of DFH-2 4 and the delay in the DFH-3 program, China in late 1992 purchased the nearly 9-year-old Spacenet 1 (May, 1984) from GTE. In 1993 the spacecraft, renamed Zhongxing 5 (aka Chinasat 5), was moved to 115.5° E. The spacecraft's payload consists of 18 C-band and six Ku-band transponders. Subsequently, China and INTELSAT reached an agreement on joint ownership of Zhongxing 5 and the to-be-launched INTELSAT 805 (References 244-251).

China also announced in 1994 a plan to deploy a GEO data relay satellite later in this decade. However, formal program approval had not yet been granted (Reference 252).

#### 4.1.21 Philippines

While a strong customer of various Western Rim communications services, the Philippines has sought during the 1990's to assemble support for a domestically owned GEO communications system. By late 1994, two commercial ventures were attempting to field potentially competing networks by the end of 1996. Each program, one led by Philippine Agila Satellite, Inc., and one led by Mabuhay Philippines Satellite Corporation, would employ Western spacecraft equipped with a mix of C-band and Ku-band transponders. More definitive plans, including a possible merger of the projects, were expected in 1995 (References 253-256).

On a related front, the Philippine Long Distance Telephone Company is one of the three principal partners in the ACES network to provide cellular phone service to parts of Asia (Section 4.1.8).

#### 4.1.22 Russian Federation

For the 20-year period from 1975 through 1994 the Russian Federation (prior to 1992, the Soviet Union) conducted an average of 16 communications missions each year. With the use of multiple-satellite launches, more than 600 individual spacecraft were placed in Earth orbit during this period into one of three regimes:

- (1) low Earth orbits,
- (2) highly elliptical, semi-synchronous orbits, or
- (3) geosynchronous orbits.

On a daily basis in 1994, approximately 80 communications satellites, from 250-2,500 kg, were operational.

The "Russian Federal Space Program to the Year 2000" identifies nearly twenty new satellite communications systems. Networks receiving federal support in addition to commercial financing include Arkos, Express-M, Gals-R, Gonets, Mayak, Signal, and Yamal. Those which must secure complete commercial backing are Bankir, Express, Gals, Gelikon, Globsat, Kondor, Koskon, Kuryer, Nord, Sokol, SPS-Sputnik, and Zerkalo.

During 1993-1994, 27 launches involving 47 communications satellites were undertaken, or 29% of all Russian space missions. Despite one launch failure, 27 LEO, 7 highly elliptical, and 12 GEO spacecraft were successfully deployed. While these numbers represent about half of the operational network (an acceptable 2-year turnover), some specific constellations have become increasingly populated with spacecraft operating beyond their design lifetimes. This situation is especially apparent in GEO.

#### 4.1.22.1 Low Earth Orbits

The lowest level of the three-tier communications satellite constellation is now populated with two distinct systems devoted to military and government communications. Both systems are assessed to be simple store-dump repeaters which are particularly useful in relaying non-essential traffic between the Russian Federation and overseas stations or forces.

The first system debuted in 1970 and consists of 750-1,000 kg satellites deployed at mean altitudes of 800 km in three orbital planes inclined  $74^\circ$  to the equator and spaced  $120^\circ$  apart. These Strela 2 spacecraft are launched separately by the Kosmos launch vehicle from the Plesetsk Cosmodrome into each orbital plane at intervals of 24-36 months in recent years. The activity of satellites can be monitored via a characteristic CW beacon emitted on a frequency of 153.660 MHz.

At the beginning of 1993 the principal members of this constellation were Kosmos 2112, Kosmos 2150, and Kosmos 2208. On 16 June 1993 Kosmos 2251 was launched to replace the oldest of the trio. Likewise, on 20 December 1994, Kosmos 2298 was placed into orbit to takeover from the then-oldest member, Kosmos 2150.

Also, debuting in 1970 was a communications system of small (61 kg, 0.80 m by 0.75 m) relay satellites launched from Plesetsk by the Kosmos booster in groups of eight (Figure

4.26). Although the mean altitude of this constellation was near 1,500 km, each set of eight Strela 1 satellites was normally dispersed into slightly elliptical orbits with mean altitudes between 1,430 km and 1,490 km. The intentional orbital period differences of about 0.15 min ensured that the satellites would become randomly spaced about the orbital plane shortly after launch. Unlike the lower altitude constellation, this network relied on a single orbital plane with an inclination of  $74^\circ$  which was replenished on the average once each year. The last mission in this program was in June, 1992, and the network has now been superseded by the more modern and capable Strela 3 system.

The Strela 3 system, which began missions in 1985, is launched by the Tsyklon-3 booster from the Plesetsk Cosmodrome into orbits near 1,400 km at inclinations of  $82.6^\circ$  with six spacecraft stacked atop each launch vehicle. Two orbital planes, spaced  $90^\circ$  apart, apparently each contain 10-12 operational spacecraft. Normally, two missions are conducted per year, suggesting an average spacecraft lifetime of approximately 24 months. Four missions were

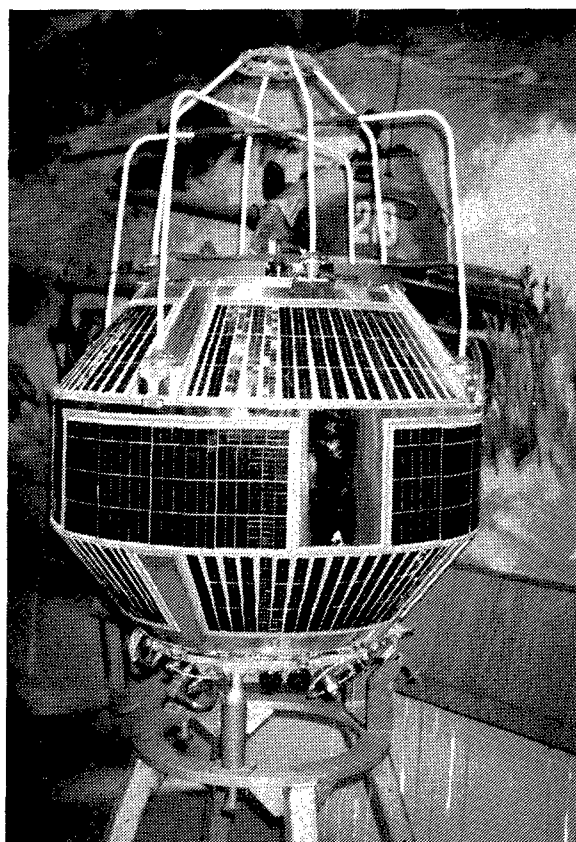


FIGURE 4.26 STRELA 1 SPACECRAFT.

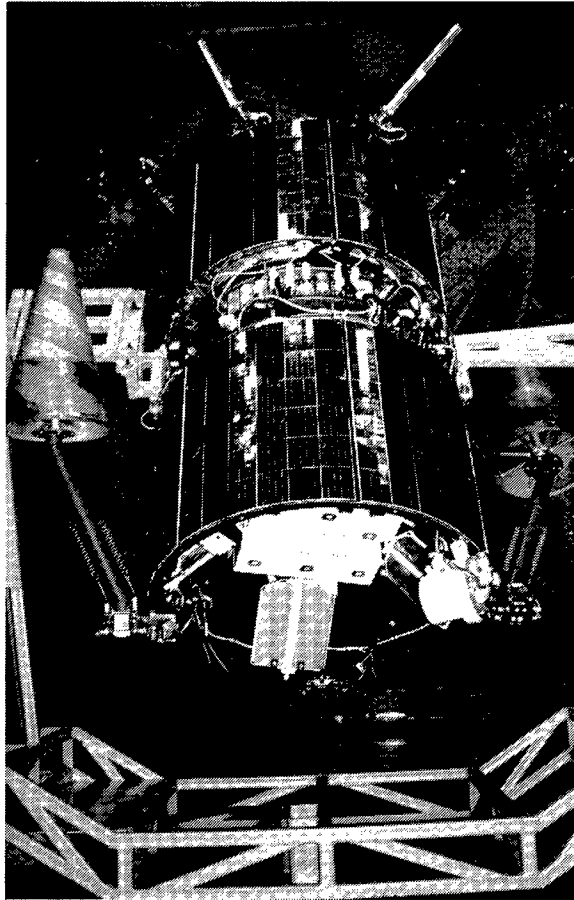


FIGURE 4.27 GONETS CLASS SPACECRAFT IN ASSEMBLY.

undertaken during 1993-1994: Kosmos 2245-2250 (May, 1993), Kosmos 2252-2257 (June, 1993), Kosmos 2268-2273 (February, 1994), and Kosmos 2299-2304 (December, 1994). The 220-kg spacecraft have a diameter of 1.0 m and a main bus height of 1.5 m. A gravity-gradient beam is extended on-orbit to provide passive attitude stabilization.

In 1990 the principal spacecraft developers (the Applied Mechanics Scientific Production Association and the Precision Instruments Scientific Production Association) began to market a slightly modified satellite as a commercial communications relay. Through the SMOLSAT Consortium in Moscow, which also includes the Soyuzmedinform Scientific Production Association and an American partner (COSSCASP, later known as Network Services International), the spacecraft have been offered to support international health organizations to meet their global communications needs, e.g., the transfer of medical data and records to remote sites. In

the commercial variant, the satellites, known as Gonets (Messenger), are capable of store/dump communications on 2-3 channels in the 200-400 MHz band with a transmitter output power of 10 W. The 250-kg Gonets are expected to be deployed at 1,350 km at 82.5°, similar to the Strela 3 satellites but distributed among 6 orbital planes for a total constellation of 36 spacecraft (Figures 4.27 and 4.28). This infrastructure should ensure a mean communication waiting time of less than 20 minutes with more than 80% probability. Attitude control is achieved through gravity-gradient stabilization. The electrical power system, provided by solar cells and nickel-hydrogen batteries, provides an average 40 W for the payload which is designed to operate for five years.

Data transmission rates available include 2.4 kbit/s, 9.6 kbit/s, and 64 kbit/s with an on-board storage capacity of 8 Mbytes. A handheld user terminal (UT-P) resembles a cellular phone and weighs only 1-3 kg. Two demonstration Gonets (Gonets D) satellites were included in the Kosmos 2197-2202 mission (specifically, Kosmos 2199 and Kosmos 2201) and were tested successfully during 1992. Three additional Gonets D spacecraft were scheduled for launch in 1993, but did not appear. The first generation Gonets system, if deployed, may be followed by an advanced Gonets-R design equipped with satellite-to-satellite links. Gonets-R may employ larger, 950-kg spacecraft in even greater numbers (45) and operate at L- and Ku-bands (References 257-263).

LEO was also the destination of a small amateur radio satellite launched on the maiden orbital mission of the Rokot booster on 26 December 1994. Dubbed Radio-ROSTO (Russian Defense, Sport, and Technical Organization), the 72-kg spacecraft closely resembled the Strela 1 communications satellite. The payload was the BRTK-11 electronic billboard (aka RS15) for use by amateur radio operators. The transponders worked at an uplink frequency band of 145.857-145.897 MHz and a downlink frequency band of 29.357-29.397 MHz with an output power of 5 W. Radio-ROSTO was inserted into an orbit of 1,884 km by 2,161 km at an inclination of 64.8° (References 264-265).

Radio-ROSTO is seen as the precursor to a proposed constellation of Radio-M spacecraft. Also launched by Rokot but into orbits of 950-1,000 km at 65°, the network would consist of up to six spacecraft working with uplink and



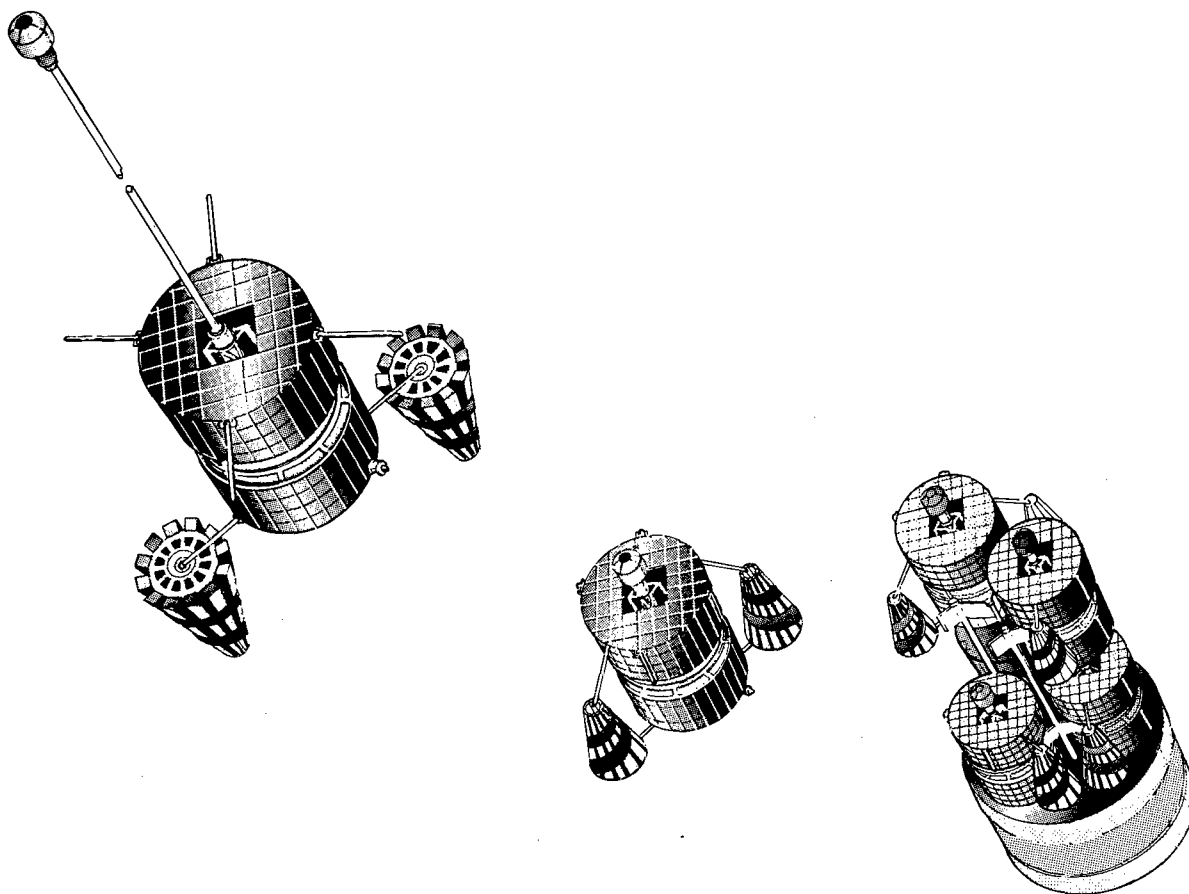


FIGURE 4.28 DEPLOYMENT SEQUENCE FOR GONETS SPACECRAFT.

downlink frequencies of 435 MHz and 146 MHz and an output transmitter power of 20 W. Radio-M spacecraft will be nearly twice as massive with a total mass of 120 kg. An alternative system would consist of six Radio-ROSTO class spacecraft in circular orbits near 1,950 km at inclinations of  $65^\circ$  (References 264 and 266). The Radio program dates back to the piggy-back launch of Radio-1 and Radio-2 in 1978, followed by Radio-3 through Radio-8 in 1981. Subsequent Radio transponders were carried by other host spacecraft (see below).

Eight new LEO communications networks have been proposed by Russian industry; but only one consortium has flown a test vehicle, and market forces will not support all concepts. On 29 January 1991 a prototype satellite for the Koskon (Space Conversion) Global Space Communication System was launched from the Plesetsk Cosmodome by the Kosmos launch vehicle. Designated Informator 1, the 600-kg satellite was inserted into an orbit of 960 km by 1,010 km at an inclination of  $83^\circ$  under the

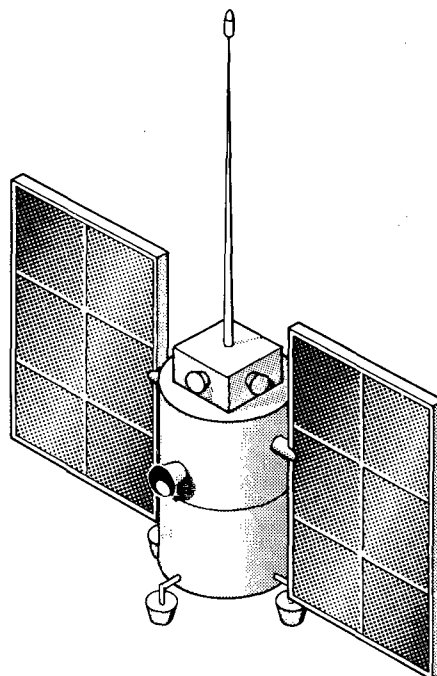


FIGURE 4.29 KOSKON SPACECRAFT.



sponsorship of the Ministry of Geology. Informator 1 was developed by the Polet Production Association and the Elas Scientific Production Association and is cylindrical in nature (diameter 1.8 m, height of 4 m) with two solar panels designed to produce 1 kW average power. Like Gonets, Informator 1 relies on gravity gradient stabilization and is projected to have an operational lifetime of 5 years or more.

The operational Koskon system will consist of 32-45 Informator-class satellites (Figure 4.29) with multiple satellites in several orbital planes. Although replacement spacecraft may continue to be launched by the Kosmos booster, the initial groups of three spacecraft are to be deployed using the Zenit booster. The first operational spacecraft may be launched as early as 1997 with deployments completed by 1998-1999. Uplink (1.656-1.660 GHz) and downlink (1.555-1.559 GHz) communications will be at a rate of 4-5 MBaud, while cross-link communications at 2.0-2.1 GHz and 0.5-1 MBaud also have been advertised. C-band transmissions may also be possible. The two primary control centers will be located in the Moscow and Omsk regions (References 261, 267-270).

Informator 1 also carried the Soviet RS14 and the German RUDAK 2 amateur satellite transponders as piggy-back payloads. Exactly one week after the launch of these amsat transponders, two more, RS12 and RS13, were placed in a virtually identical orbit as secondary

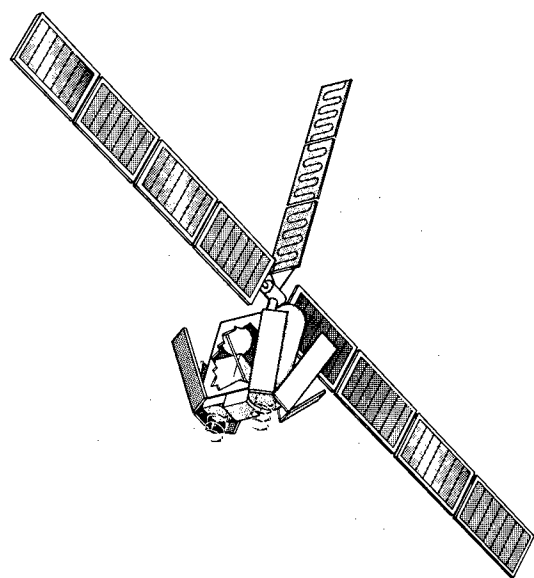


FIGURE 4.30 CONVERT SPACECRAFT.

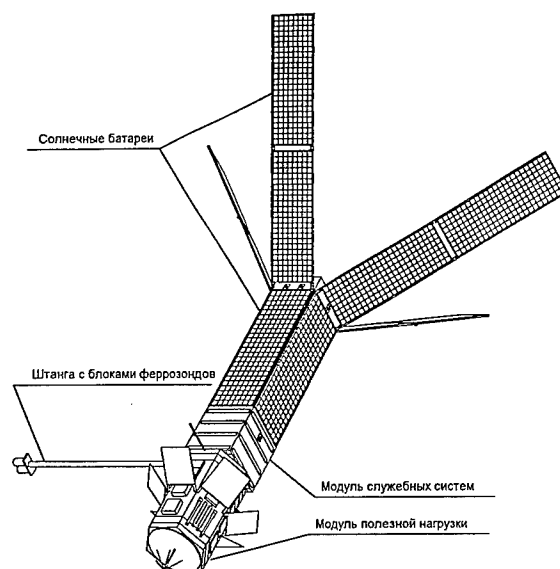


FIGURE 4.31 SIGNAL SPACECRAFT.

payloads to the Kosmos 2123 navigation satellite. Several such amsat transponders were developed at the Kaluga Electromechanical Plant under the direction of Aleksander Papkov and were launched by the USSR during 1978-1991 (Reference 271).

The Elas Scientific Production Association is also a principal participant in the proposed Kuryer communications system of Convert spacecraft. The current network design calls for 8-12 of the 500-kg satellites (Figure 4.30) to be deployed in 700 km orbits with 76° inclinations by the Start-1 launch vehicle. With a primary objective of supporting "e-mail" and other communications, the Kuryer system may operate at 430-470 MHz with helical antennas and later at L-band with phased array antennas. Optical satellite crosslinks have also been mentioned. The small spacecraft will be powered by two long, narrow solar arrays and will reject heat via a liquid radiator. The flight testing program was to begin in 1993 but was delayed until 1995 at the earliest (References 261, 272-274).

The RKK Energiya and Polet PO have teamed up with other industries to field the Signal constellation of LEO satellites. Up to 48 of these 310-kg spacecraft (12 satellites in each of four orbital planes) will fly at altitudes of 1,500 km with inclinations of 74°. Launches will be conducted either by Kosmos boosters with two spacecraft or by Tsyklon boosters with six spacecraft. The long and narrow spacecraft (Figure 4.31) will have a payload capacity of

70 kg and a design lifetime of six years. The current design includes UHF, L-band, and Ku-band transponders. Like several of its competitors, Signal has suffered program delays, and the launch of the first prototype spacecraft has slipped until at least 1995 (References 261, 262, 275-277).

The Makeyev Design Bureau in Miass has proposed a constellation of LEO communications satellites based, in part, on its extensive experience in naval systems, including submarine-launched ballistic missiles. The SPS (Personal Satellite Communications System) - Sputnik network would consist of 32-48 spacecraft of 300 kg mass in orbits of 510 km with inclinations of  $70^\circ$ . The system is design for voice, digital, and facsimile communications via direct or electronic mail methods. The primary communications link will be in the 300-400 MHz band with a possible extension to C-band. SPS-Sputnik spacecraft, with design lifetimes of five years, will be launched by Shtil-1N boosters, perhaps beginning in 1995 (References 261, 278-279).

The Salyut Design Bureau chose perhaps the least ambitious of all Russian LEO communications systems. Its Globsat constellation would consist of only 3-6 spacecraft at an altitude of 1,000 km and an inclination of  $65^\circ$ . These 150-kg spacecraft would be launched in groups of three with Salyut's Rokot booster. Unlike other systems, Globsat is designed for real-time communications during limited contact periods, e.g., 10 minutes for users within a 300-km region. Links would be via the 300-400 MHz band. System deployment, which could be accomplished with only one or two launches, was not scheduled until 1995 or later (References 261 and 280).

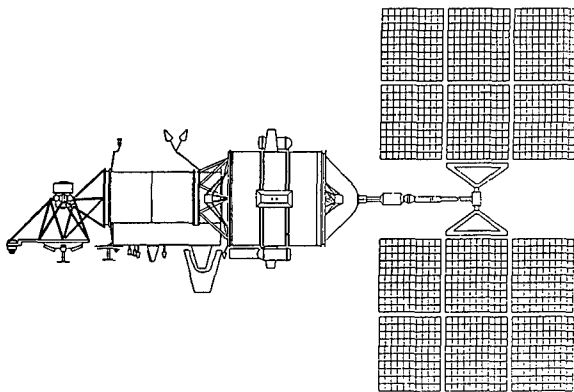


FIGURE 4.32 ELEKON SPACECRAFT.

Two other, less defined and less likely to emerge, concepts are Pallada and Radiobook. The former network has been devised by the Moscow Radiocommunication Research Institute for regional, i.e., CIS, communications services, including voice, telegraph, fax, and data transmissions. The constellation of 36 spacecraft would orbit the Earth at an altitude of 1,640 km at an inclination of  $63^\circ$  and would employ C-band channels (Reference 281). The Radiobook, on the other hand, would utilize from 24 to 36 micro-satellites (10 kg or less) for a packet radio network which could be launched with much smaller boosters, including air-launched missiles. The principal applications would be e-mail and limited, non-realtime personal communications (Reference 282).

In 1990 the Lavochkin NPO announced plans to create a LEO communications network of 4-8 satellites operating in the UHF band (400-480 MHz) by 1994 (Reference 283). However, in 1992 the Bankir project had evolved into a geosynchronous satellite system employing new Coupon satellites. This concept is described below with other future GEO systems.

The final LEO system, which is already far along in development, is actually a hybrid communications-navigation system called Elekon. With a team of Science and Technology International of Russia (STIR) and Elbe Space and Technology of Dresden, Germany, the Elekon program seeks to replace the existing two Russian LEO navigation systems (Section 4.2.6) and at the same time implement a low-cost vehicle/container tracking and messaging network. The latter payload consists of L-band, S-band, and C-band transponders which will operate from a 900-kg platform orbiting the Earth at an altitude of 1,150 km (Figure 4.32). The constellation will use seven spacecraft in different orbital planes and with an expected lifetime of 3-5 years. An Elekon payload was tested in orbit on the GEO-IK 1 satellite (launched 29 November 1994). The first operational vehicle was not scheduled for launch until the latter part of 1995 at the earliest (References 284-286).

#### 4.1.22.2 Highly Elliptical Orbits

The second stratum of the Russian space-based communications system consists of 16 Molniya-class spacecraft in highly elliptical, inclined ( $63^\circ$ ) semi-synchronous orbits. With initial perigees between 450 and 600 km fixed

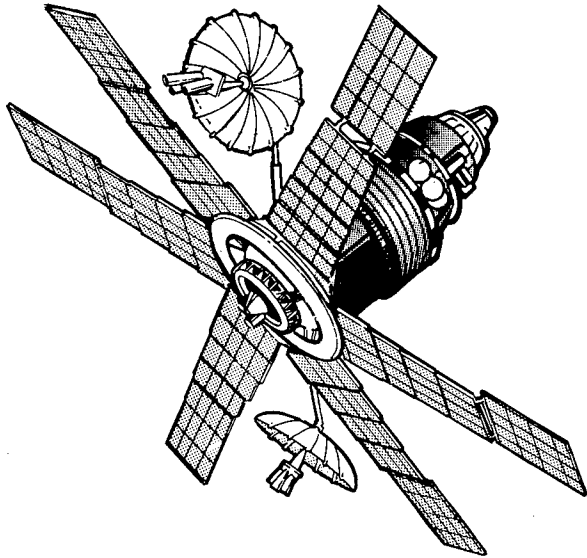


FIGURE 4.33 ORIGINAL MOLNIYA 1 SPACECRAFT.

deep in the Southern Hemisphere and apogees near 40,000 km in the Northern Hemisphere, Molniya satellites are synchronized with the Earth's rotation, making two complete revolutions each day (orbital period of 718 minutes). The laws of orbital mechanics dictate that the

spacecraft orbital velocity is greatly reduced near apogee, allowing broad visibility of the Northern Hemisphere for periods up to eight hours at a time. By carefully spacing 3-4 Molniya spacecraft, continuous communications can be maintained. This type of orbit was pioneered by the USSR and is particularly suited to high latitude regions which are difficult or impossible to service with geostationary satellites.

The first prototype Molniya satellite was launched in 1964 and to date more than 150 have been deployed. Primarily produced by the Applied Mechanics NPO in Krasnoyarsk, Molniya satellites weigh approximately 1.6 metric tons at launch and stand 4.4 m tall with a base diameter of 1.4 m. Electrical energy is provided by six windmill-type solar panels producing up to 1 kW of power (Figure 4.33). A liquid propellant attitude control and orbital correction system maintains spacecraft stability and performs orbital maneuvers, although the latter usage is rarely needed. Sun and Earth sensors are used to determine proper spacecraft attitude and antenna pointing.

The 16 operational Molniya satellites are divided into two types and four distinct groups.

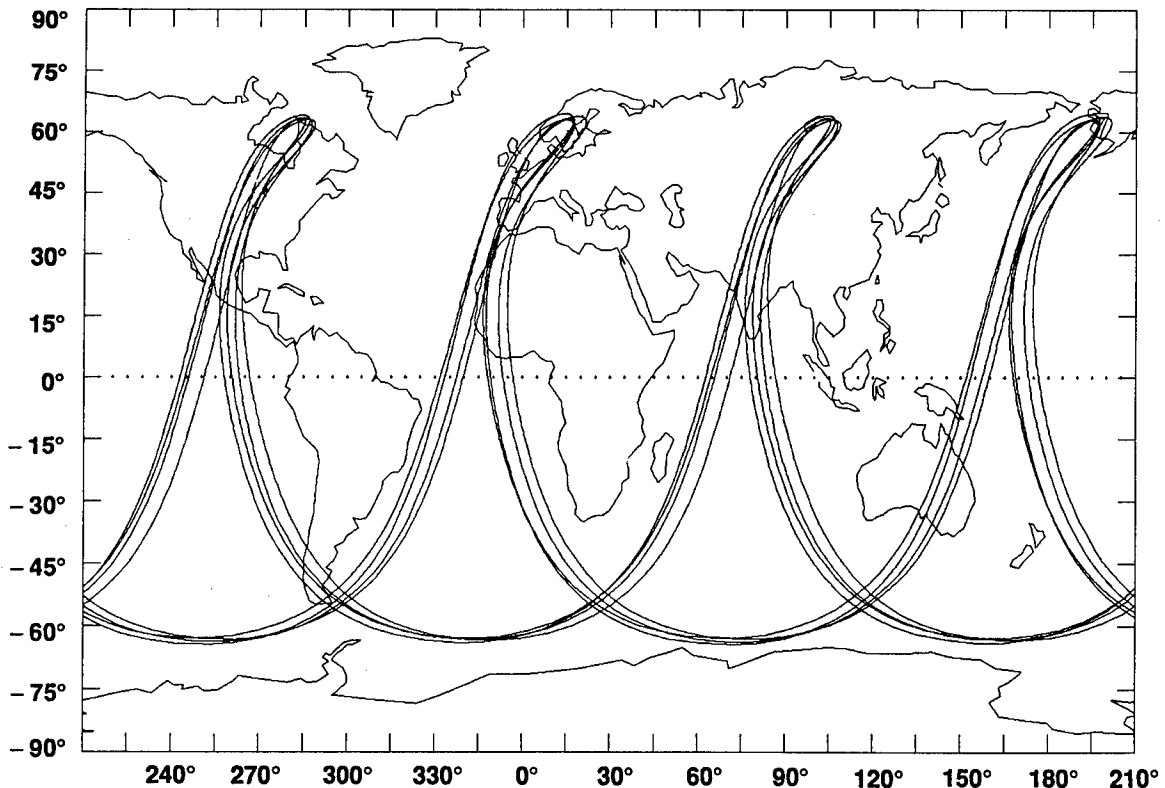


FIGURE 4.34 TYPICAL MOLNIYA 1 AND MOLNIYA 3 GROUNDTRACKS.

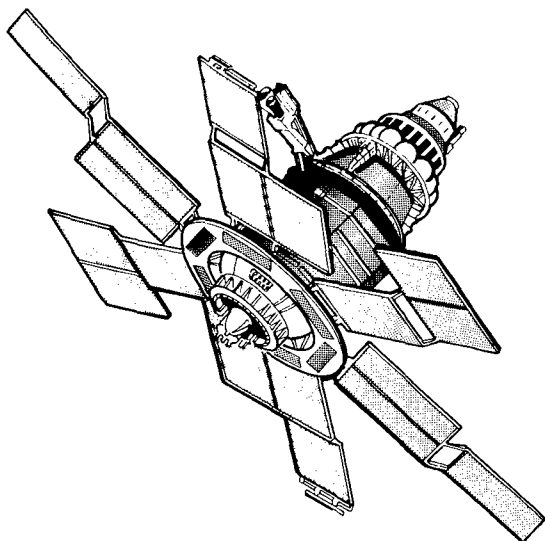


FIGURE 4.35 MOLNIYA 3 SPACECRAFT.

Eight Molniya 1 satellites are divided into two constellations of four vehicles each. Both constellations consist of four orbital planes spaced  $90^\circ$  apart, but the ascending node of one constellation is shifted  $90^\circ$  from the other, i.e., the Eastern Hemisphere ascending nodes are approximately  $65^\circ$  and  $155^\circ$  E, respectively (Figure 4.34). Although the system supports the Russian Orbita Television network, a principal function is to service government and military communications traffic via a single 40 W, 1.0/0.8 GHz transponder. Since Molniya 1-75 in 1989, all Molniya 1 spacecraft have been launched from the Plesetsk Cosmodome by the Molniya booster.

Half of the Molniya 1 constellation was replenished during 1993-1994. In 1993 Molniya's 1-85, 1-86, and 1-87 replaced Molniya's 1-78, 1-81, and 1-77, respectively. The sole Molniya 1 launch of 1994, Molniya 1-88, relieved Molniya 1-82 of its duties. At the end of 1994, these four new spacecraft were working with Molniya's 1-79, 1-80, 1-83, and 1-84. The oldest spacecraft in the constellation, Molniya 1-79, had just turned four years old in November, 1994. All currently operational Molniya 1 spacecraft are of the Molniya 1T class which was introduced in the 1970's.

The first Molniya 3 spacecraft (Figure 4.35) appeared in 1974, primarily to support civil communications (domestic and international), with a slightly enhanced electrical power system and a communications payload of three 6/4 GHz transponders with power outputs of 40 W or 80 W. Although the launch requirements are the same for Molniya 1 and Molniya 3 and although

Molniya 1 satellites have been launched from either Plesetsk or Baikonur, Molniya 3 spacecraft have only originated from Plesetsk. Until 1983 the Molniya 3 constellation consisted of only four satellites which were essentially co-located with four Molniya 1 satellites. When the Molniya 3 system was expanded to eight vehicles in 1983-1985, the new additions inaugurated the  $155^\circ$  E ascending node geometry. After the restructuring of the Molniya 1 constellations in 1991, the Molniya 1 and Molniya 3 systems are essentially the same from a deployment perspective and to some extent provide an inherent backup capability.

On the average Molniya 3 spacecraft are replaced slightly less frequently than their Molniya 1 cousins, representing an apparent longer operational life by 5-6 months. Two Molniya 3 spacecraft were launched in 1993, Molniya 3-44 and Molniya 3-45, to replace Molniya's 3-41 and 3-37, respectively. Like the Molniya 1 constellation, the Molniya 3 network received only one new number in 1994: Molniya 3-46 to replace Molniya 3-40. Thus, at the end of 1994 the Molniya 3 constellation consisted of these three new spacecraft as well as five older spacecraft (Molniya's 3-36, 3-38, 3-39, 3-42, and 3-43). The oldest spacecraft was five years old.

In 1990 the Applied Mechanics NPO announced that it was developing a successor to the Molniya series of spacecraft. The latest design for the Mayak spacecraft (Figure 4.36) closely resembles the Arcos GEO spacecraft, with which it will form the Marathon communications system (see below). The total on-orbit mass will be 2,500-3,000 kg which includes a payload mass of 580 kg. Mayak will support both L-band and C-band communications and

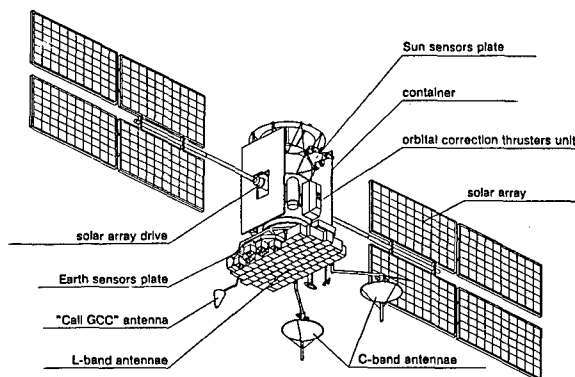


FIGURE 4.36 MAYAK SPACECRAFT.

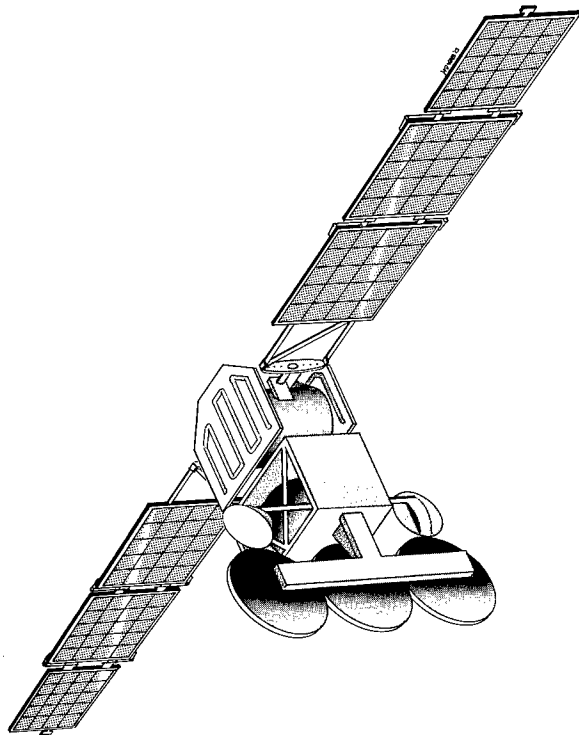


FIGURE 4.37 TYULPAN SPACECRAFT.

will be compatible with INMARSAT standards. Four spacecraft will comprise the Mayak system and the design lifetime for each vehicle will be twice that of Molniya: 5-7 years. The first launch of a Mayak spacecraft by the new Rus launch vehicle will not come until 1997 or later, five years after the original schedule (References 262 and 287).

The Lavochkin NPO has proposed highly elliptical communications systems under two different names: Nord and Tyulpan. Nord was described in 1992 as a 4-satellite network of 2,300-kg spacecraft launched by the Rus booster. The 3-axis-stabilized spacecraft were to be based on military spacecraft, a short, cylindrical bus with two S-shaped solar arrays. The 600-kg payload was to service both fixed and mobile users and be in orbit by 1994-1995 (Reference 288).

Recently Lavochkin's Tyulpan has been promoted more heavily. Retaining several Nord system characteristics, the Tyulpan network would employ 2,400-2,600-kg spacecraft with a different design (Figure 4.37). The two solar arrays will generate up to 1.5 kW, and ion engines will perform attitude control and orbit maintenance functions. The 670-kg payload will include C-band and Ku-band transponders. Six spacecraft are needed for the Tyulpan network

which maximizes the 8-hour visibility of each spacecraft by coordinating the operation of the C-band and Ku-band transponders. The former with steerable antennas can be used at lower altitudes, whereas the Ku-band transponders primarily operate with fixed antennas near apogee (Reference 289).

#### 4.1.22.3 Geosynchronous Earth Orbits

The Soviet use of geosynchronous satellites for telecommunications purposes did not begin until the mid-1970's. By the end of 1994 more than 100 communications and data relay spacecraft had been placed in geosynchronous orbits with 36 still operational near 27 positions along the geostationary ring (Table 4.3). During 1993-1994 a total of 12 GEO communications spacecraft were deployed under six program names: Raduga, Gorizont, Kosmos, Luch, Gals, and Express. The last two represented the maiden flights of the next generation Russian GEO communications spacecraft.

Russian GEO spacecraft differ from most other GEO satellites by their greater mass (2-2.5 metric tons in GEO), their lesser communications capacity, and, until 1994, their lack of north-south station-keeping ability. The last characteristic is evident in the continual variation of orbital inclinations (typically between 0-5 degrees) of Russian GEO satellites during their operational lifetimes. To minimize this effect, new satellites have been launched with initial GEO orbital inclinations of 1-2 degrees under strict conditions which take advantage of solar-lunar perturbations first to reduce the inclination to zero over a period of one to two years before it increases. East-West station-keeping is accomplished with liquid propulsion or ion thrusters.

To date, the development of all Russian GEO communications satellites has been directed by the Applied Mechanics NPO under the leadership of Mikhail Reshetnev. The Radio NPO and the Institute of Space Device Engineering are the primary communications payload developers, and the Astra NPO is the principal supplier of ground stations and receivers. Although USSR/Russian satellites are often characterized by short lifetimes in comparison to analogous Western satellites, these Siberian-made spacecraft exhibit normal mission lives of 5-10 years. All GEO satellites are transported to Baikonur for launch by the Proton boosters. With rare exceptions the spacecraft are inserted

TABLE 4.3 RUSSIAN GEO COMMUNICATIONS SPACECRAFT, 1 JANUARY 1995.

EQUATORIAL POSITION (E)	HOST SPACECRAFT OR SYSTEM						
	RADUGA	GORIZONT	GEYSER	EKRAN	GALS	EXPRESS	LUCH
12	RADUGA 22 RADUGA 29						
35	RADUGA 28						
40		GORIZONT 22					
45	RADUGA 31						
49	RADUGA 1-2 RADUGA 1-3						
53		GORIZONT 27					
70	RADUGA 25 RADUGA 32 RADUGA 1-1					EXPRESS 1	
71					GALS 1		
80		GORIZONT 24	KOSMOS 2085 KOSMOS 2291				
85	RADUGA 30						
90		GORIZONT 28					
95							LUCH 1
96.5		GORIZONT 19					
99				EKRAN 19 EKRAN 20			
103		GORIZONT 25					
128	RADUGA 27						
130		GORIZONT 29*					
134		GORIZONT 17*					
140		GORIZONT 18					
142.5		GORIZONT 30*					
145		GORIZONT 21					
190	RADUGA 21						
335	RADUGA 23						
344							KOSMOS 2054
346		GORIZONT 20					
346.5			KOSMOS 1888 KOSMOS 2172				
349		GORIZONT 26					

\* Leased to Rimsat

into GEO near 90° E and allowed to drift east or west to their intended stations.

The first Russian GEO series spacecraft were the Raduga military and government communications satellites which appeared in 1975. Since then the Raduga constellation has expanded to 12 spacecraft distributed among 9 locations for global coverage. The general configuration of Raduga spacecraft is unknown, but the launch mass is approximately 2.0 metric tons. Up to six 6/4 GHz transponders are car-

ried on each satellite. In addition, Raduga spacecraft may host Gals (8/7 GHz), Luch P (14/11 GHz), and Volna (1.6/1.5 GHz) transponders. A new series of Raduga spacecraft, designated Raduga 1, debuted in 1989.

During 1993-1994 five Raduga-class spacecraft were launched and successfully deployed in GEO, while three older spacecraft were retired, increasing the total number of operational satellites of this type to 13 with the oldest member seven years old. Raduga 29 was

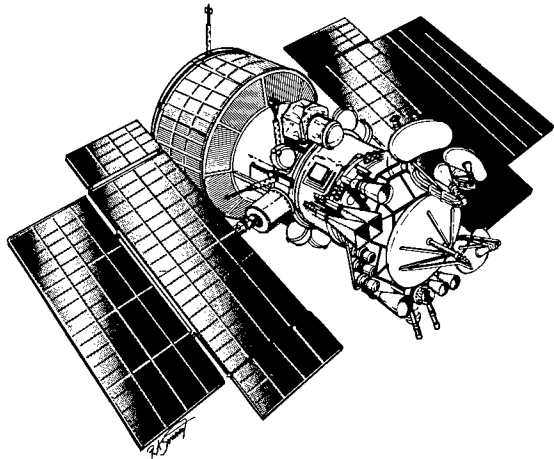


FIGURE 4.38 GORIZONT SPACECRAFT.

launched on 25 March 1993 and joined Raduga 22 at 12° E. Raduga 30 followed on 30 September 1993 and was transferred to 85° E. Raduga 26, which had been stationed at 85° E, began a series of small maneuvers coincident with the launch of Raduga 30, and the older satellite was placed in a graveyard orbit.

Two more standard Raduga spacecraft were launched in 1994: Raduga 31 on 18 February and Raduga 32 on 28 December. Raduga 31 replaced Raduga 24 at 45° E, allowing the latter to drift off-station shortly thereafter. Raduga 32, on the other hand, was sent to join Raduga 25 and Raduga 1-1 at 70° E. The third standard Raduga spacecraft to retire during 1993-1994 was Raduga 19, which shared the 35° E slot with Raduga 28. Raduga 19 performed an end-of-life maneuver in September, 1993. Raduga 1-3 was the only Raduga 1 type spacecraft launched during the period, and it joined Raduga 1-2 at 49° E after launch in February, 1994.

The equally populous Gorizont satellites are primarily used for domestic and international communications. In use since 1979, the Gorizont constellation established a tenth position in the GEO ring for domestic needs and deployed three Gorizonts (one old, two new) to new locations in support of Rimsat, Ltd., the US-based firm leasing orbital slots from Tonga. In all, four Gorizont spacecraft were launched during 1993-1994, but one was lost due to a Proton launch failure. With no resident spacecraft being retired during the period, the number of active Gorizonts increased by the end of 1994 to 13.

The Gorizont spacecraft (Figure 4.38) possesses an initial mass in excess of 2.1 metric tons and has demonstrated a lifetime of nearly 10 years, although a 5-year service life is more common. The 3-axis stabilized satellite is approximately 2 m in diameter and 5 m long with two large solar arrays capable of generating 1.3 kW of electrical power for the first three years. Seven separate transmission antennas permit a variety of reception patterns for both broad and localized terrestrial regions.

A typical Gorizont communications payload includes six general purpose (TV, audio, facsimile) 6/4 GHz transponders (five 12.5 W and one 60 W), one Luch 14/11 GHz transponder (15 W), and one Volna 1.6/1.5 GHz transponder (20 W). The Volna transponders are INMAR-SAT-compatible and are extensively used by the Russian merchant marine fleet via the primary control center in the Tomilino suburb of Moscow and the Odessa and Nakhodka ground stations. Gorizont is the primary GEO television rebroadcasting system, supporting all five federation time zones: Zone 1 from 140° E, Zone 2 from 90° E, Zone 3 from 80° E, Zone 4 from 53° E, and Zone 5 from 14° W. These transmissions are handled by Orbita (12-m receiving antenna) and Moskva (2.5-m receiving antenna) ground stations in the 6/4 GHz band. The Moskva Globalnaya system was inaugurated in 1989 using 4-m receiving antennas and serviced by Gorizonts at 96.5° E and 11° W (Reference 290).

The first Gorizont launch attempt in 1993 on 27 May failed due to propellant contamination in the second and third stages, resulting in the spacecraft splashing down in the Pacific Ocean. After the Proton returned to service in late September, two Gorizonts were deployed in the final quarter of the year. Gorizont 28, launched

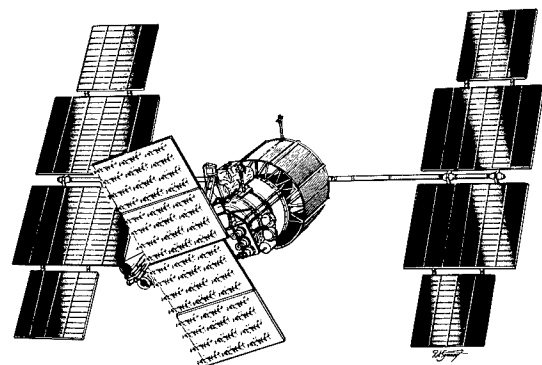


FIGURE 4.39 EKRAN-M SPACECRAFT.

on 28 October replaced Gorizont 21 at  $90^{\circ}$  E. This allowed Gorizont 21 to be repositioned from mid-November to late-December for the inauguration of a new station at  $145^{\circ}$  E.

Gorizonts 29 (18 November 1993) and 30 (20 May 1994) were launched for Rimsat, Ltd., to provide communications services in the Pacific region under an agreement signed in 1992 between Rimsat and the Applied Mechanics NPO. Gorizont 29 was located at  $130^{\circ}$  E, and Gorizont 30 settled in at  $142.5^{\circ}$  E in accordance with a lease arrangement with Tonga which had been authorized use of those slots by the International Telecommunications Union. The Rimsat network had actually been initiated earlier when Gorizont 17 was transferred from  $53^{\circ}$  E (where it was a backup to Gorizont 27) to  $134^{\circ}$  E during late-June and July, 1993. At the close of 1994, Gorizont 17 was still on station but nearing the end of its operational life after six years (References 291-300).

A third Russian system, Ekran-M, provides unique direct television broadcasting service to the central federation region (Zone 3). The original Ekran spacecraft debuted in 1976 and were upgraded to the Ekran-M model in the second half of the 1980's. All spacecraft in the series have been positioned near  $99^{\circ}$  E and transmit directly to simple individual or communal receivers at 0.7 GHz with a powerful 200 W transponder. The new Ekran-M spacecraft (Figure 4.39) weigh approximately two metric tons and carry two transponders. The solar arrays have been augmented to provide 1.8 kW of power.

Although the original Ekran spacecraft were exceptionally short-lived, the new Ekran-M are markedly surpassing the cited 3-year design life. No new Ekran-M spacecraft were launched during 1993-1994, but the 6-year-old Ekran 19 and the 2-year-old Ekran 20 were still on station at the start of 1995. Although a replacement for the Ekran-M system has been discussed for several years (see below), a new model Ekran, called Ekran-D, has been proposed to permit digital transmissions of a broader assortment of information (References 301-302).

Two other Russian telecommunications systems have been operating in GEO for many years aboard Kosmos spacecraft. Beginning with Kosmos 1366 in 1982, the Potok data relay system has primarily supported military and government users. Potok transponders are hosted on Geyser satellites and utilize a unique, hexagonal phased-array antenna. The principal

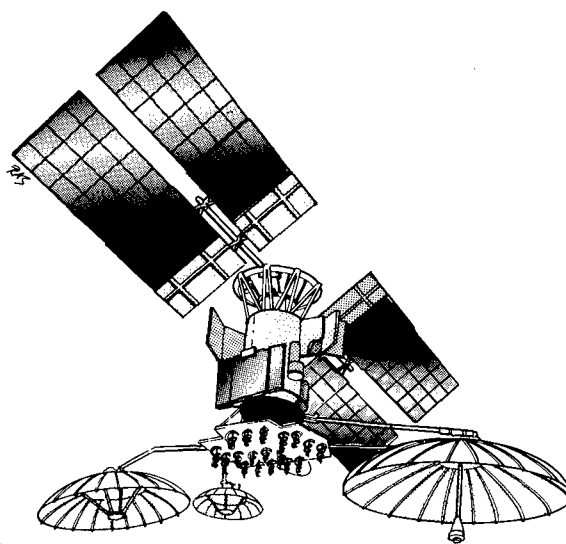


FIGURE 4.40 LUCH SPACECRAFT.

ground stations for the Potok system are located at Nakhodka and in the Moscow region at Konakovo. From Geyser spacecraft positioned at  $80^{\circ}$  E and  $13.5^{\circ}$  W, the Potok system is designed for document and digital data transmissions in C-band. A third GEO slot at  $168^{\circ}$  W has not yet been opened. Mobile and stationary transmitter/receiver stations are used with antenna diameters of 2.6-3 m as well as compact phased-array antennas. In 1992 Russian officials offered the Geyser-Potok system for commercial international use under the name Sokol (References 303-307).

On 21 September 1994, the eighth of the Geyser spacecraft was launched under the name of Kosmos 2291. The vehicle quickly moved to  $80^{\circ}$  E, joining Kosmos 2085. In September, 1993, Kosmos 2085's previous companion had begun drifting off station after its mission of five years had apparently been terminated. Thus, at the end of 1994 the Potok constellation had been restored to its normal 4-satellite complement: Kosmos 2085 and 2291 at  $80^{\circ}$  E and Kosmos 1888 and 2172 at  $13.5^{\circ}$  W.

A second GEO telecommunications system initially hidden within the Kosmos program is the Satellite Data Relay Network (SDRN) which is analogous to the U.S. Tracking and Data Relay Satellite System (TDRSS). Three Luch spacecraft (not to be confused with the Luch transponder system on Gorizont spacecraft) were launched between 1985 and 1989: Kosmos 1700, Kosmos 1897, and Kosmos 2054.



Although three locations have been registered with the International Telecommunications Union ( $16^{\circ}$  W,  $95^{\circ}$  E, and  $160^{\circ}$  W), only the first two have been employed to date.

Each Luch spacecraft (also referred to as Altair satellites) has a mass of 2.4 metric tons and two extended solar arrays capable of supplying 1.8 kW (Figure 4.40). Three large antennas and numerous, small helical antennas permit data relays in the 15/14, 15/11, and 0.9/0.7 GHz bands. Terrestrial stations may employ simple 0.8-2 m antennas. The system is especially well suited for space-to-space communications, including the Mir space station and the now canceled Buran space shuttle. The Luch spacecraft has a design lifetime of 5 years (References 308 and 309).

At the beginning of 1993 the only operational Luch spacecraft was Kosmos 2054, stationed at  $16^{\circ}$  W. Finally, on 16 December 1994 Luch 1 was launched and later positioned at  $95^{\circ}$  E. This 2-satellite network is now used primarily in support of the Mir space station program.

The year 1994 also marked the long-awaited debut of the first of the next-generation Russian GEO communications satellites. These spacecraft, designed and built by the Applied Mechanics NPO, utilize a new, modernized MSS-2500 class bus with greater electrical power, higher precision station-keeping capabilities (including north-south station-keeping), and longer life. The first of these spacecraft to appear was Gals 1 on 20 January 1994, followed by Express 1 on 13 October. Both employed the MSS-2500-GSO-01 spacecraft bus. Two other models (MSS-2500-GSO-02 and MSS-2500-GSO) are still under development.

The Gals television broadcasting satellite (Figure 4.41), originally expected to be launched by December, 1990, is designed to support a variety of direct broadcast customers,

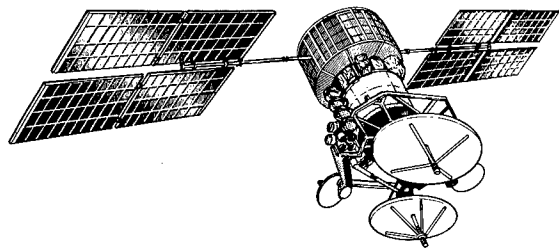


FIGURE 4.41 GALS SPACECRAFT.

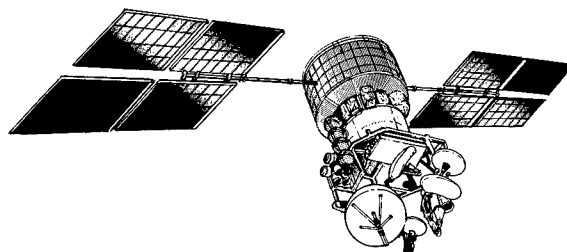


FIGURE 4.42 EXPRESS SPACECRAFT.

including professional broadcasting firms (receiving antenna 2.5 m in diameter), communal associations (receiving antenna 1.5 m), and individuals (receiving antenna 0.6-0.9 m). The 2,500-kg spacecraft with a payload mass of 420 kg was originally scheduled for deployments at only two locations:  $23^{\circ}$  E with three spacecraft and  $44^{\circ}$  E with two spacecraft. Later, positions at  $74^{\circ}$  E,  $110^{\circ}$  E, and  $140^{\circ}$  E were added. The constellation may be altered to consist of spacecraft at  $36^{\circ}$  E,  $56^{\circ}$  E,  $86^{\circ}$  E,  $110^{\circ}$  E, and  $140^{\circ}$  E. Two solar arrays with a total power of 2.4 kW support three Ku-band transponders (one 40 W and two 80 W). The spacecraft bus measures 4.1 m by 6.6 m with a 21-m span across the solar arrays. The design lifetime is 5-7 years (References 311-316).

Like most Russian GEO spacecraft, Gals 1 was inserted into the GEO ring near  $90^{\circ}$  E. A western drift was assigned to permit the vehicle to reach  $44^{\circ}$  E by early February, 1994. After an initial checkout during which problems were detected with one of the three transponders, Gals 1 was unexpectedly transferred to  $71^{\circ}$  E during May-June to service, not the Russian Federation, but the PRC and Taiwan. Gals 1 remained at  $71^{\circ}$  E for the remainder of 1994 (References 312, 317-319).

Gals 1 also signaled the first civilian control of a major applications spacecraft. The new Main Control Center at Krasnoyarsk in Siberia (home of the Applied Mechanics NPO), rather than the military satellite control facility at Golitsyno-2, was in charge of Gals 1's day-to-day operations. Gals 1 further tested the Russian SPT-100 ion thruster created by the Fakel Design Bureau. This evaluation program was conducted in conjunction with France's SEP firm and U.S.'s Loral Space Systems Company (References 318, 320-322).

Three modifications of Gals are already envisioned. Gals-R will add a fourth transponder and permit zonal (broad area) television

broadcasting. The Gals-R6 and Gals-R12 variants will carry 6 and 12 transponders, respectively. The first launch of a Gals-R vehicle was tentatively set for 1996. Two Gals-R class spacecraft have reportedly been ordered by a Chinese company for launches beginning in 1998 (References 262, 313, 323-324).

Nine months after Gals 1 was launched, Express 1 was inserted into a nearly GEO orbit. The Express series spacecraft closely resemble the Gals spacecraft which share a similar spacecraft bus (Figure 4.42). Express will replace the widely used Gorizont spacecraft, and current plans call for deployments at 13 locations (40°, 53°, 80°, 90°, 96.5°, 99°, 103°, 140°, 145°, 205°, 322.5°, 346°, and 349°, all East longitude) just for domestic needs and to support the Intersputnik Telecommunications Association. Additional Express spacecraft may be sold to foreign companies, e.g., Rimsat, Ltd. While the Express solar arrays are identical to those on Gals, the spacecraft bus has slightly smaller dimensions of 3.6 m by 6.1 m. A typical Express payload will include 10 C-band and two Ku-band transponders. Express 1 reached its checkout location of 70° E at the end of October and was scheduled to be moved to 14° W shortly after the start of 1995 (References 262, 323, 325-328).

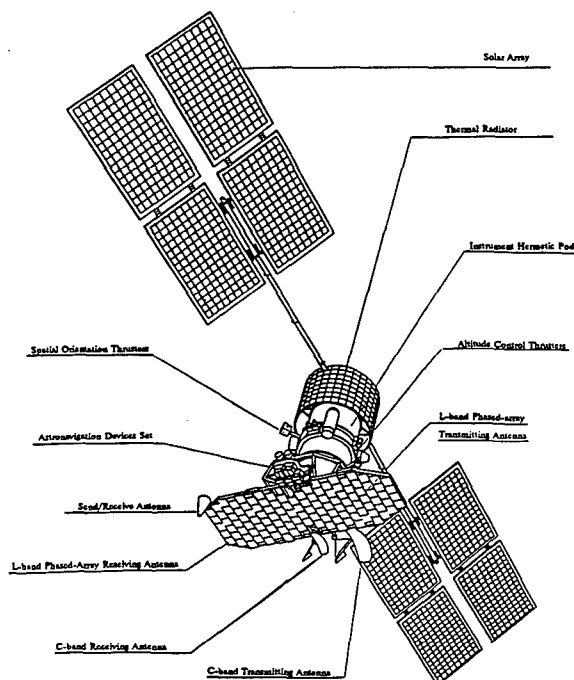


FIGURE 4.43 ARKOS SPACECRAFT.

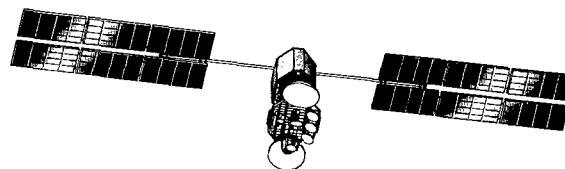


FIGURE 4.44 GELIKON SPACECRAFT.

Eight additional new spacecraft types are currently in various stages of development, including the first proposed GEO communications spacecraft produced outside of the Applied Mechanics NPO. The next new spacecraft likely to appear will be Applied Mechanics' Arkos satellite, which will serve as the GEO anchor of the Marathon telecommunications network while the highly elliptical Mayak spacecraft complete the system. Arkos spacecraft are specifically designed to service mobile (air, land, and sea) and remote users.

The design of Arkos (Figure 4.43) has evolved several times since the first concepts, and the present configuration relies upon the basic MSS-2500 bus (like Gals and Express), but the payload carries a phased-array primary antenna (two of the Mayak-class antennas). The spacecraft will carry a typical payload of three transponders for INMARSAT-compatible C-band and L-band communications. The full constellation will require five spacecraft positioned at 40°, 90.5°, 145.5°, 200°, and 346.5° E. Arkos is expected to beat its Mayak sister satellite into orbit with a launch sometime in 1996 (References 262, 323, 329-330).

An early Applied Mechanics NPO plan to replace Gorizont and Ekran spacecraft revolved around the Gelikon project. Although the Gelikon schedule has slipped (as have all new Russian GEO communications spacecraft), the Gelikon program still officially enjoys government approval, although no government funding. Gelikon satellites will be deployed at five GEO positions (one for each of the major broadcast time zones): 23° E, 44° E, 74° E, 110° E, and 140° E. Although the launch mass of Gelikon will be the same as Gals and Express (2.5 metric tons), Gelikon will carry augmented solar arrays (span of 26.9 m) which will provide up to 5.2 kW for the expected ten-year lifetime. Instead of the three transponders on Gals, the Gelikon payload will include 12 Ku-band units which will also work with the variety of receiving stations identified above for Gals. The Gelikon spacecraft bus (Figure 4.44) differs in appear-

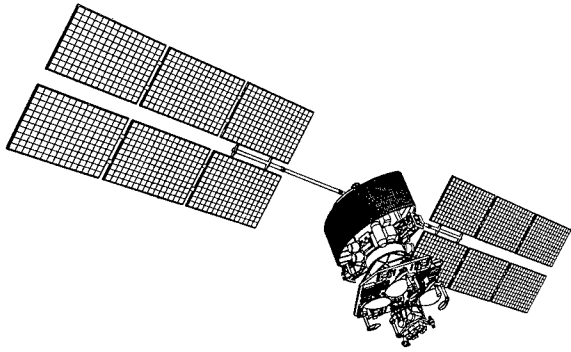


FIGURE 4.45 SOVCANSTAR SPACRAFT.

ance from that of Gals and Express with overall dimensions of 6.2 m by 6.8 m. The first launch of Gelikon was set for 1995, but further delays are anticipated (References 331-332).

One of the early Russian-Western satellite programs was SovCanStar, a joint venture between the Applied Mechanics NPO and a Canadian association of Com Dev Ltd., Canadian Satellite Communications, Inc., and General Discovery in 1990. Under the agreement the Russian side was to provide the spacecraft bus and the launch service (Proton), while the Canadians supplied the communications payload. The 2,600-kg SovCanStar spacecraft was designed to carry 24 Ku-band transponders (75 W output power) with four spares. The first two spacecraft were slated for 145° E and 14° W, and three additional locations to be determined later. The spacecraft bus bears a strong resemblance to that of Gelikon which was being designed about the same time. The design life of SovCanStar is 10 years with a first launch now expected about 1998. A preliminary plan to start the SovCanStar system quickly with Gorizont spacecraft was abandoned after the designated Gorizont vehicle was lost in the Proton accident of 27 May 1993 (References 333-343).

A similar project between Russia and Germany was significantly altered in 1992. Known as Romantis, the original plan envisioned a German consortium providing the communications payloads for Russian-built-and-launched satellites. Later, German industry assumed responsibility for the complete development of the spacecraft. Then, in late 1992 the scope of the project was reduced with the German team now focusing on the manufacture of ground stations and the lease of INTELSAT links between the CIS and Europe (References 73, 344-347).

As noted above, the Lavochkin NPO proposed in 1990 the creation of a LEO store/dump communications network called Bankir. However, 1992 documents from Lavochkin NPO indicated the Bankir name was now used in reference to a geostationary communications system comprised of Coupon satellites of the Globostar Satellite Communications System. The Bankir network began operations in 1993 via the existing Potok system of Geyser spacecraft. By 1997 a constellation of four Coupon spacecraft is envisioned at locations above the eastern Atlantic (9.5° W) and the eastern and western Indian Ocean (55° E, 86.5° E, and 91.75° E).

Each 2.5-metric-ton Coupon will employ sophisticated phased-array antennas for transmission footprints tailored to user specifications. The basic spacecraft will carry 16 Ku-band transponders. The Coupon spacecraft bus is derived from the newest generation missile detection satellites. The Bankir network is being organized by the newly established Russian firm of Global Information Systems, Inc. The Elas NPO will provide the transponders and the ground stations (References 288, 323, 348-355).

In 1991 Lavochkin NPO teamed up with NOOS Space Technologies Ltd. of Moscow to develop the Zerkalo spacecraft and telecommunications system. The Zerkalo spacecraft will take advantage of some of Coupon's systems but will be heavier at just over 3,000 kg and will use conventional antennas (Figure 4.47). The

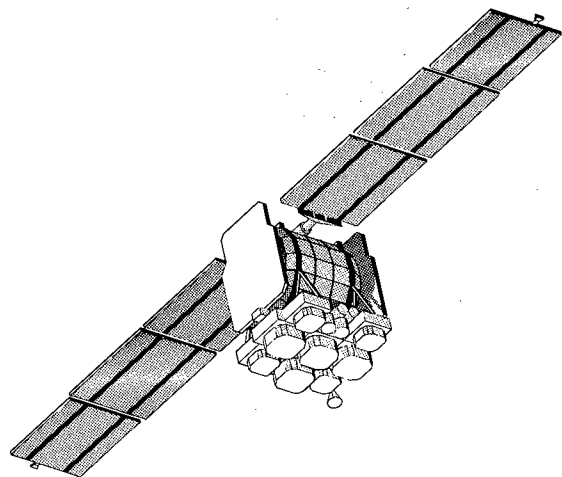


FIGURE 4.46 COUPON SPACECRAFT.

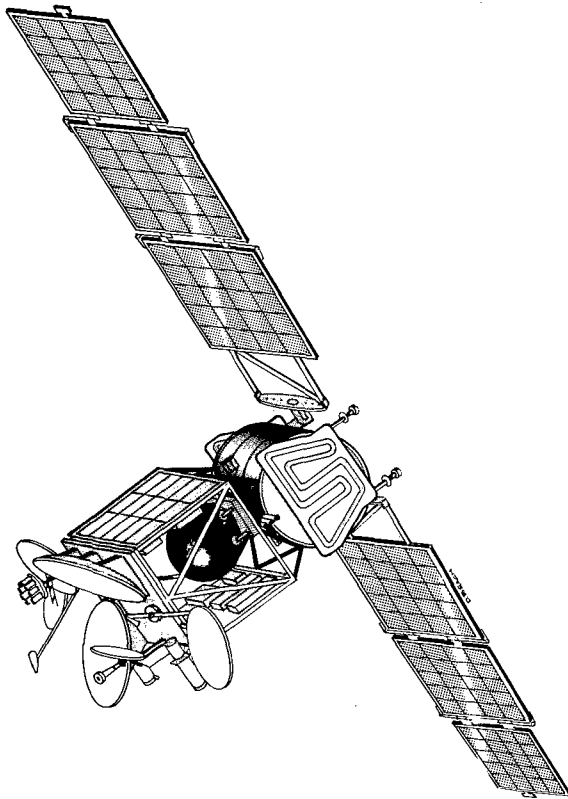


FIGURE 4.47 ZERKALO SPACECRAFT.

solar array will produce up to 2.96 kW with 1.4 kW available to the communications payload which will operate in the Ku-band with 10 transponders. The design life of the single spacecraft which will be stationed at  $88.1^\circ$  E is 5-7 years. The first Zerkalo launch is planned for 1995 or later (References 288, 351, 356-358).

A third Lavochkin vision in association with Moscow NII Radiocommunication is the creation of a GEO and highly elliptical communications system analogous to Applied Mechanics' Marathon. Dubbed Geostar-MSS, the constellation would consist of three spacecraft in GEO and four spacecraft in Molniya-type orbits. The yet-to-be-defined satellites would be equipped with Ku-band transponders. The program appeared to be in an early stage of development in 1994, and no date for a first launch was set (Reference 359).

One of Lavochkin's cross-town rivals, the Khrunichev State Space Research and Production Center (including the Salyut Design Bureau), has proposed the Kondor communications system for mobile users. This 4-satellite system would be based on 2.5-2.6 metric ton spacecraft with 3.2 kW electrical power systems. The communications payload could have

a mass up to 500 kg and a power requirement of 1.5 kW. The transponders would be of the L-band and C-band types and INMARSAT-compatible. The L-band transponders would be high power (200-250 W) and be linked to two 6-m diameter antennas. A specific start date for Kondor operations has not been given, but in 1994 initial activities were said to be possible during 1995-1997 (Reference 360).

RKK Energiya has also decided to enter the GEO communications satellite arena. With the Gazkom Joint Stock Company, RKK Energiya is developing the Yamal communications satellite with plans to deploy two vehicles, one at  $75^\circ$  E and one at  $19.5^\circ$  W. Yamal is the smallest of the proposed GEO spacecraft with a total mass of 1.3-1.4 metric tons, including a payload mass of up to 310 kg (Figure 4.48). The box-like spacecraft bus will carry two solar arrays capable of producing 2.4 kW at the end of the 10-year design life. A single primary dish antenna will support the nine C-band transponders. A combination of liquid and ion engines will be used for spacecraft attitude and orbit maintenance. Due to their compact size and low mass, Yamal spacecraft can be launched two at a time by a Proton booster. The first mission is due in 1997 (References 323, 361-362).

Clearly the most ambitious GEO communications satellite project was led by the Energiya NPO (prior to its becoming RKK Energiya) with the objective of launching enormous telecommunications platforms with masses of up to 20 metric tons in GEO. First proposed in 1989 as a means of coordinating and consolidating numerous national communications systems, the idea of a high-cost, high-capacity GEO satellite was received with muted enthusiasm.

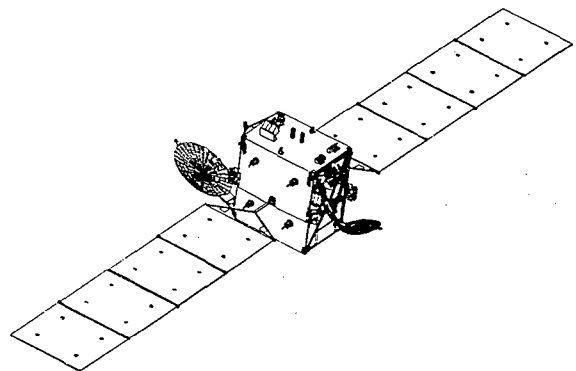


FIGURE 4.48 YAMAL SPACECRAFT.

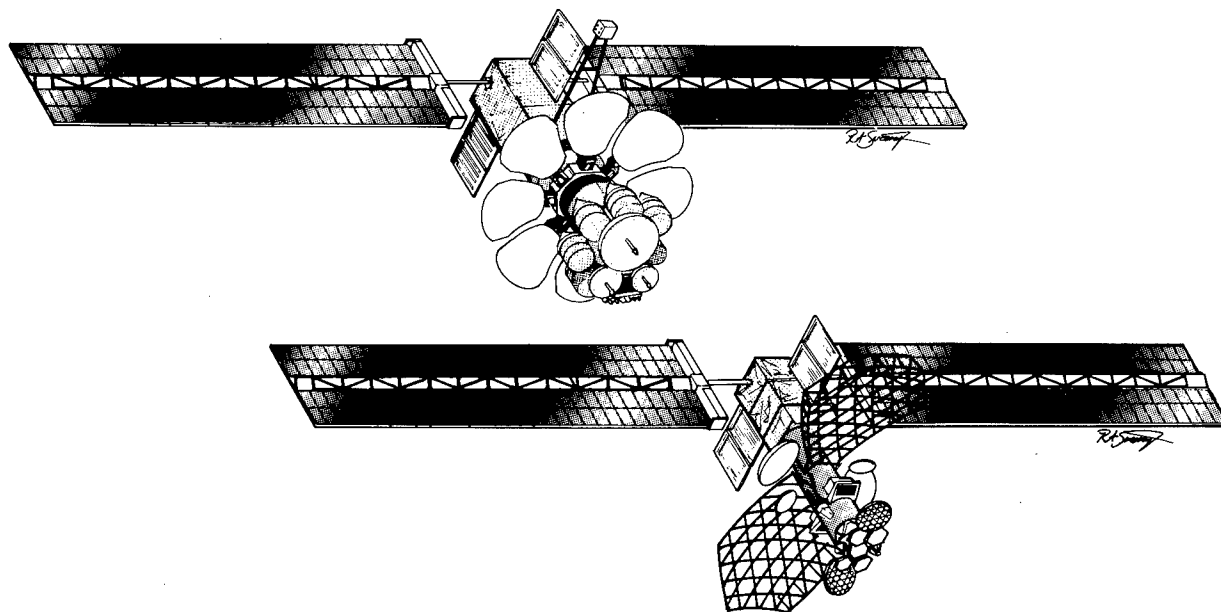


FIGURE 4.49 PROPOSED CONFIGURATIONS FOR LARGE RUSSIAN GEO SPACECRAFT.

While providing one solution to the problem of overcrowding in the GEO ring (reportedly, three platforms could replace 32 conventional GEO satellites), the concern about a launch failure of the Energiya booster or of an on-board support system (e.g., attitude control) which would cause the loss of the entire spacecraft was difficult to overcome (Figure 4.49).

Under the original Energiya NPO and Energiya-Marathon Association proposal, a Phase 1 system (1994-1997) would include three 17.8 metric ton platforms to meet USSR internal communications needs as well as communications with Europe and Asia. The 7.6-metric-ton payload would draw 12 kW from the total 16 kW on-board power supply to operate a host of transponders at 1.6/1.5 GHz, 6/4 GHz, 14/11 GHz, and 18/12 GHz through antennas ranging from 1 to 8.5 m in diameter. The design lifetime was rated at 10 years.

If successful, a Phase 2 system (1997-2000) might be deployed with 4-5 even larger satellites to form a Global Space System. A total platform mass of 20 metric tons could support a 9 metric payload package and a 24 kW electrical power supply system. Antenna dimensions would grow to up to 20 m in diameter, while transponder frequencies would increase to 60/50 GHz. To increase the payload capacity of the Energiya launch vehicle, a two-stage liquid oxygen/hydrocarbon upper stage would be

replaced with a single liquid oxygen/liquid hydrogen upper stage. Although financing for the project was in hand in 1992, the cancellation of the Energiya launch vehicle program ended the super-heavy Globis satellite project. However, as late as October, 1994, such platforms were still being proposed (References 363-368).

#### 4.1.23 Saudi Arabia

Saudi Arabia is the headquarters of the Arab Satellite Communications Organization which has operated the Arabsat GEO telecommunications system since 1985. With more than 20 member countries, the organization fills a vital role of communications in North Africa and the Middle East for many nations which do not need nor can afford dedicated satellite networks. By the end of 1994, the Arabsat system had been reduced to only one spacecraft, but a new generation of satellites is planned for launches beginning in 1996.

The three Arabsat 1 spacecraft are based on the Aerospatiale and MBB Spacebus 100 platform which was also employed for the EUTELSAT 2 series. Ranging from nearly 600 kg to almost 800 kg at the start of life in GEO, the spacecraft measure 1.5 m by 1.6 m by 2.3 m with a solar array span of about 21 m for 1.4 kW of electrical power. The primary communications payload consists of two S-band tran-

sponders and 25 C-band transponders. The nominal design life was seven years.

Arabsat 1A was launched by Ariane on 8 February 1985 but immediately suffered a solar panel extension malfunction. Other failures quickly relegated the spacecraft to backup status until late 1991 when the vehicle was abandoned. Arabsat 1B was launched by the U.S. Space Shuttle and was operated near 26° E from June, 1985, until the summer of 1992 when it, too, no longer continued station-keeping operations. Arabsat 1C was launched by Ariane on 26 February 1992 and was still on station near 31° E at the end of 1994.

As a stop-gap measure to maintain network services until the Arabsat 2 spacecraft become available, the organization leased the Canadian Anik D2 spacecraft (November, 1984) in 1993. Renamed Arabsat 1D, the vehicle was moved from the Western Hemisphere during April-August 1993 to a position at 20° E. Arabsat 1D is based on a Hughes HS-376 bus and originally carried 24 active C-band transponders.

A contract for two Arabsat 2 spacecraft was signed with Aerospatiale in April, 1993. The spacecraft will utilize Aerospatiale's Spacebus 3000 platform to carry 22 C-band transponders (including eight 52 W moderate power transponders) and 12 Ku-band transponders. Arabsat 2 spacecraft will have a mass of more than two metric tons on station. The maximum dimensions of the spacecraft bus will be 1.8 m and 2.3 m, and the solar array span will be 25 m for a 5 kW electrical power capacity. The launch of Arabsat 2A is scheduled for 1996 with Arabsat 2B to be followed as needed to maintain a strong 2-satellite constellation. Although Arabsat 2A will be launched by Ariane, the Proton booster is being considered for Arabsat 2B (References 369-371).

#### 4.1.24 Singapore

During 1994 Singapore Telecommunications teamed with Pasifik Satelit Nusantara of Indonesia and Hughes to form a joint venture for mobile telecommunications services in the Asian theater. From this start, the Asia Pacific Mobile Telecommunications company was born, but the Indonesian partner was replaced with PRC government investors. Program details were still sketchy at the end of 1994, but initial operations as early as 1998 were an objective. Meanwhile, Singapore Telecommunications was examining the possibility of operat-

ing its own spacecraft for television broadcasting and telephone services by 1997-1998. The spacecraft would likely carry C-band and Ku-band transponders for its principal mission (References 372-373).

#### 4.1.25 South Korea

South Korea's first two spacecraft were based on the UK's Surrey Satellite Technology Ltd. (SSTL) microsatellite design. Kitsat 1 (aka Uribyol 1, 10 August 1992) and Kitsat 2 (aka Uribyol 2, 26 September 1993) were carried as piggyback passengers on Ariane flights to LEO. Although neither of the spacecraft were true communications satellites, both were equipped with a modest store-and-forward messaging capability (References 374-377).

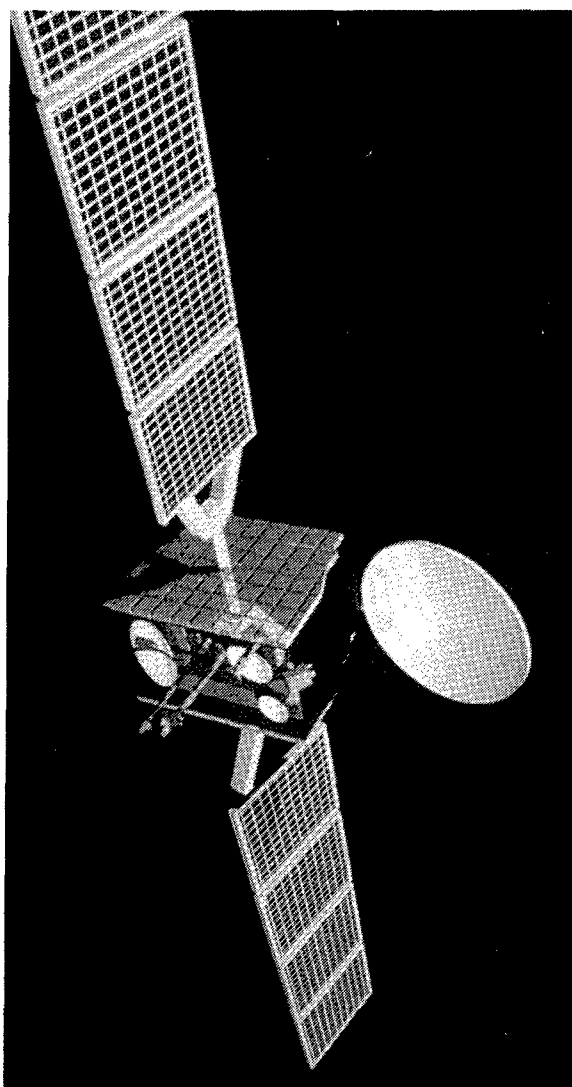


FIGURE 4.50 HISPASAT 1 SPACECRAFT.

The long-range goal of South Korea is to develop its own spacecraft. A step in this direction was taken with Kitsat 2, which was assembled in South Korea from UK components. The next step is the much delayed, dual-purpose Komsat. Relying heavily on a TRW spacecraft bus and engineering expertise, South Korea will assist in the design and manufacture of Komsat which will perform remote sensing as well as serve as a communications relay. The 400-kg spacecraft will be inserted into a 685-km, sun-synchronous orbit in 1998 or 1999 (References 378-382). South Korea has discussed a similar venture with the PRC (References 383-385).

Unable to construct its own GEO communications spacecraft, South Korea contracted with Lockheed-Martin for two 3000 series satellites to be launched in 1995. The Koreasat (aka Mugunghwa) spacecraft will have a mass of about 830 kg on station and will carry 15 Ku-band transponders of which three will be high power (120 W). Both spacecraft will be positioned at 116° E with expected design lives of 10 years (References 386-387).

#### 4.1.26 Spain

Spain's first GEO communications satellite was launched by Ariane in September, 1992, as Hispasat 1A (Figure 4.50) and positioned at 30° W. The launch of a sister satellite, Hispasat 1B, followed 10 months later. Based on the Eurostar spacecraft bus developed by British Aerospace and Matra Marconi, Hispasat is designed to support civil, military, and government communications requirements through an array of multi-frequency transponders.

With an on-orbit mass of 1.1 metric tons, the government-owned Hispasat 1A carries 15 active transponders: three X-band with one spare and 12 Ku-band (8 at 55 W, 4 at 110 W) with six spares. The Hispasat bus measures 1.7 m by 1.9 m by 2.1 m with a solar array span of 22 m and an initial power capacity of 3.2 kW. A problem with the Spanish-manufactured primary antenna on Hispasat 1A, led Matra Marconi to procure an Aerospatiale antenna for Hispasat 1B. The spacecraft design life is ten years. From its position over the Atlantic Ocean, Hispasat is capable of servicing not only Europe but also North and South America (References 388-390).

#### 4.1.27 Sweden

Originally conceived as the birth of a Scandinavian telecommunications network, includ-

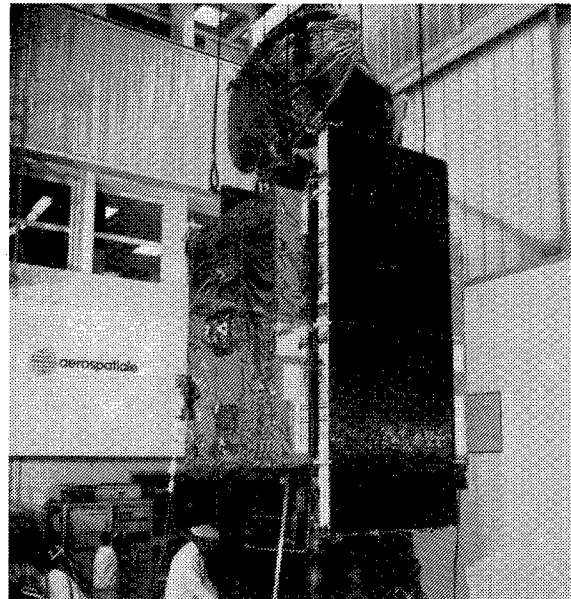


FIGURE 4.51 TELE-X SPACECRAFT.

ing Denmark, Finland, Iceland, Norway, and Sweden, Tele-X now represents a national Swedish asset with greatly reduced objectives and prospects. Launched on 2 April 1989 by Ariane, the Tele-X spacecraft (Figure 4.51) is located at 5° E with tailored coverage primarily for Finland, Norway, and Sweden.

Based on the Aerospatiale and MBB Spacebus 300, Tele-X has an on-orbit mass of 1.3 metric tons and a design life of up to eight years. The 3-axis stabilized vehicle measures 1.7 m by 2.4 m by 2.4 m with a solar array span of 19 m and a electrical capacity in excess of 3 kW. The communications payload consists of four Ku-band transponders.

In December, 1993, Sweden followed Norway's lead by purchasing the UK's Marcopolo 1, aka BSB R1, spacecraft (Norway had acquired Marcopolo 2 in 1992). Rechristened Sirius, Marcopolo 1 (Figure 4.52) was transferred to a position near Tele-X in early 1994. Sirius' payload includes six Ku-band transponders and should function until the end of the decade; Sirius was launched in 1989 with a 10-year lifetime (References 391-392).

With its shorter design life, Tele-X is likely to fail before Sirius, possibly about 1997. In anticipation of this event, Sweden was preparing in late 1994 to place an order for a Sirius 2 spacecraft and possibly a Sirius 3 vehicle as well. Although not definitized, Sirius 2 will probably carry a payload with several times the capacity of either Tele-X or Sirius. The launch of Sirius 2 is tentatively planned for 1997 to

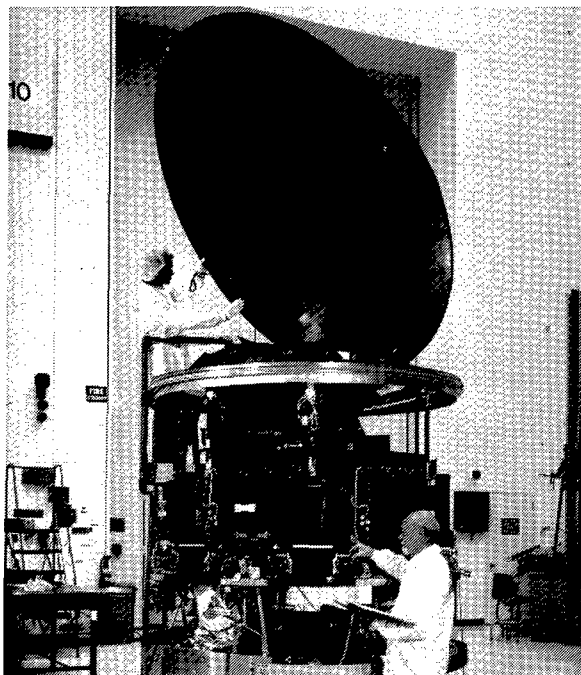


FIGURE 4.52 SIRIUS SPACECRAFT, FORMERLY BSB (MARCOPOLO).

avoid a service disruption when Tele-X reaches its end of life (Reference 393).

#### 4.1.28 Taiwan

In the early 1990's Taiwan adopted a long-range plan for acquiring technologies related to developing and operating spacecraft. The National Space Program Office was subsequently established to oversee a 15-year program which envisioned the launch of three LEO spacecraft with foreign assistance. The multi-discipline Rocsat program will include telecommunications payloads on at least the first two missions.

Rocsat 1, scheduled for launch in 1998, will be built by TRW and will carry a Ka-band communications relay experiment. The communications payload will be built and integrated by Taiwan's Microelectronics Technology. The 400-kg spacecraft will be placed into a low altitude, low inclination orbit (~600 km, 35°) by a U.S. LLV booster. Rocsat 2, with a more capable communications payload is tentatively scheduled for launch in the year 2000. Integral Systems, Inc., of the US will provide the satellite control facility for the Rocsat program (References 394-398).

#### 4.1.29 Thailand

Thailand inaugurated its first national GEO communications network during 1993-1994 with

the launches of Thaicom 1 (18 December 1993) and Thaicom 2 (8 October 1994) by Ariane boosters. The spacecraft, based on Hughes HS-376L series, are operated by the Shinawatra Satellite Company of Bangkok under a lease arrangement with the Thai government. Both Thaicom satellites are stationed at 78.5° E with ten C-band and two Ku-band transponders. The 630-kg spacecraft have a design life of at least 13 years. However, in late 1994 Thailand was nearing selection of a foreign vendor to provide a Thaicom 3 satellite with up to 24 C-band and 14 Ku-band transponders for launch as early as 1996 (References 399-403).

#### 4.1.30 Turkey

Turkey had hoped to emulate Thailand by quickly launching two GEO communications satellites to form an "instant" network. Unfortunately, Turksat 1A was lost on 24 January 1994 in an Ariane accident. Turksat 1B fared much better after its launch on 10 August of the same year and was successfully positioned at 42° E. The spacecraft is based on the Aerospatiale Spacebus 2000 series with an on-orbit mass of slightly more than one metric ton. The communications payload consists of 16 Ku-band transponders with an expected operational life of 10 years or more. A contract for Turksat 1C to replace Turksat 1A was signed with Aerospatiale in 1994 for a launch in 1996 (References 404-406).

#### 4.1.31 Ukraine

With its considerable space technology experience and expertise gained during the USSR years, Ukraine views the development of a multi-purpose national space program as a logical move and consistent with its military conversion policies. Early on the National Space Agency of Ukraine set telecommunications and remote sensing as its initial objectives. While Ukraine already possessed considerable experience in the latter, e.g., via the USSR Okean program, communications satellites had previously been a primarily Russian endeavor.

An early concept by the Ukrainian-Russian company Ariadne envisioned establishing a LEO constellation of small communications satellites which could be launched by Ukraine's Tsyklon booster. Later, government emphasis switched to a GEO communications system which might rely on foreign assistance to develop the spacecraft and which could be



launched by the Zenit-3 currently under development. As late as December, 1993, the National Space Agency hoped to launch two "television and communications" spacecraft manufactured by the Yuzhnoye design bureau by the year 2000. The 1.2-metric-ton spacecraft would be able to service Ku-band needs. However, by early 1994, Ukraine had reached an agreement with Matra Marconi (after more than a year of discussions) to provide a communications spacecraft to Ukraine for launch in 1997 under the Lebid program. Ukraine has also applied to the ITU for a GEO position of 64.5° E to support X-band communications (References 407-414).

#### 4.1.32 United Kingdom

The United Kingdom was the third entity to operate a telecommunications satellite in GEO, after the United States and INTELSAT. Its Skynet military communications network has been operational since 1974 following abortive starts in 1969 and 1970. A civilian direct broadcasting system, known as Marcopolo or BSB, debuted in 1989, but those assets have recently been sold to Norway and Sweden. The University of Surrey has earned an international reputation for low cost, high quality microsatellites, which have been used by several countries for modest communications tasks.

The first attempt of the UK to establish an independent and secure space-based communications systems faltered in 1969-1970 when Skynet 1A failed prematurely and Skynet 1B was lost in a launch malfunction. Whereas the Skynet 1 spacecraft were American-made, the Skynet 2 series which appeared in 1974 were designed and manufactured by the British firm of Marconi Space and Defense Systems with assistance from Philco-Ford. Skynet 2A was also lost in an unsuccessful launch attempt in January, 1974. However, the spin-stabilized, 240-kg Skynet 2B was orbited in November, 1974, and provided regular service for more than 18 years. The spacecraft was still functioning as it neared its 20th anniversary in space (References 415-416).

Although the follow-on Skynet 3 system never materialized, the current Skynet 4 series of spacecraft was successfully deployed during 1988-1990. Built under the direction of British Aerospace and derived from its earlier OTS and ECS satellites, Skynet 4 satellites are 3-axis

stabilized with an initial on-orbit mass of slightly less than 800 kg. The spacecraft bus dimensions are 1.4m by 1.9 m by 2.1 m with a 1.2 kW solar array span of 16 m (Figure 4.53). The communications payload includes three X-band transponders and two UHF transponders.

The current Skynet 4 constellation consists of three spacecraft: Skynet 4A (launched 1 January 1990) located near 326° E, Skynet 4B (launched 11 December 1988) located near 53° E, and Skynet 4C (launched 30 August 1990) located near 1° W. Skynets 4B and 4C were launched by Ariane, whereas Skynet 4A was launched by the U.S. Titan 3. With design lifetimes of only seven years, two more Skynet spacecraft are scheduled for launch later in this decade: 4D and 4E in 1997-1998. A variant of the Skynet 4 spacecraft has also been flown under the NATO 4 series. A pan-European military communications system, perhaps as Skynet 5, is under consideration for launch soon after the turn of the century (References 417-419).

Since 1981 the University of Surrey and later Surrey Satellite Technology Limited (SSTL) have been successfully deploying 50-kg-class microsatellites for LEO store/dump communications, primarily for use by the amateur radio community. Designated UoSAT, the first of these satellites was launched as a piggyback with the U.S. Solar Mesospheric Explorer in October, 1981. UoSAT 2 accompanied the U.S. Landsat 5, while UoSAT 3 and 4 hitched a ride on the SPOT 2 mission. UoSAT 5 was launched along with ESA's ERS-1 on 17 July 1991 and was a repeat of the UoSAT 4 vehicle which had malfunctioned almost immediately after launch.

The French S80/T and the South Korean Kitsat 1 were also Surrey products launched in 1992. The following year PoSAT 1 and Healthsat 2 joined the list of Surrey-produced satellites, while Kitsat 2 was constructed with Surrey components. Two more Surrey satellite platforms are expected to fly in 1995: France's CERISE and Chile's FASat Alpha.

The standard SSTL modular spacecraft bus has a mass of 50 kg (including a 7-10 kg payload) and dimensions of 33 cm by 33 cm by 60 cm. Silicon or gallium arsenide solar cells generate 30 W at beginning of life with 8-10 W average for the payload in a LEO polar orbit. Attitude system pointing accuracy is less than five degrees (References 420-422).

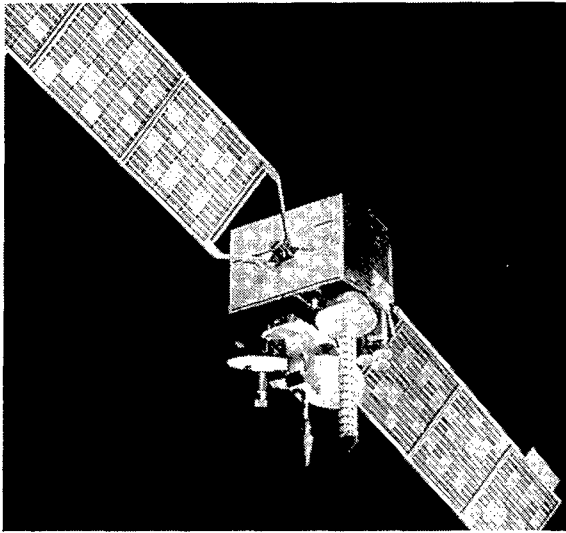


FIGURE 4.53 SKYNET 4 SPACECRAFT.

## 4.2 NAVIGATION AND GEODESY

One of the first practical applications of artificial satellites was to aid in terrestrial navigation. Although only the US and Russia operate navigation satellite systems, these networks are available to users everywhere on land, at sea, or in the air. Increased accuracies, nearly instantaneous information, and the development of international standards have prompted an explosive growth in the use of satellite navigation aids. The PRC has acknowledged its intent to enter this field during the 1990's, while INMARSAT will add navigation to its current communications services with the introduction of the INMARSAT 3 generation spacecraft beginning in 1996.

Although even the earliest satellites provided new, valuable data on the nature and shape of the Earth, dedicated geodetic satellites now support specific civil, scientific, and military requirements. Russian, French, Italian, and Japanese geodetic spacecraft are already in Earth orbit, while numerous other satellites carry laser reflectors, which can be used for geodetic studies, as a matter of course.

### 4.2.1 European Space Agency

Although the ESA Navsat concept dates back to the 1980's, the proposed project has received relatively little attention and even less financial support. The preliminary Navsat system called for 18 satellites: 12 in highly elliptical orbits and 6 in geostationary orbits (Reference 423). By mid-1993 ESA was examining plans

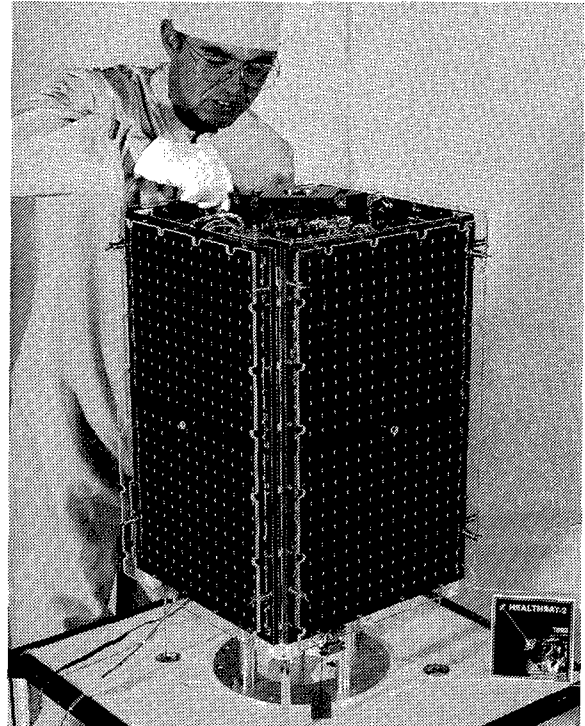


FIGURE 4.54 TYPICAL SSTL MICROSATELLITE (HEALTHSAT-2).

for a Global Navigation Satellite System (GNSS) for the express purpose of avoiding European dependency on the US GPS and the Russian GLONASS networks. However, behind the scenes activities were aimed at finding an acceptable sponsor and operator other than ESA, perhaps the European Commission or INMARSAT. Formal Phase A/B studies were postponed until 1995 or later.

### 4.2.2 France

To date France has not deployed a satellite navigation network, and plans to establish the Locstar system of two geostationary satellites for position-determination services were abandoned in July, 1991, when sufficient funds could not be raised (References 424). The system would have combined navigation aids with a data and message service but would have been limited to a restricted operational region between Europe and North Africa.

France is one of the four founding nations of the COSPAS-SARSAT search and rescue system (Section 4.2.8) and operates a LUT (Local User Terminal) at Toulouse. However, no COSPAS-SARSAT transponders are currently carried aboard French spacecraft. Since 1988

the CNES subsidiary CLS (Collecte Localisation Satellites) in conjunction with NASA and NOAA has operated a satellite-based location system under the Argos World Service network. Argos transponders attached to NOAA spacecraft can provide users equipped with a Platform Transmitter Terminal (PTT) position information accurate to about 350 m.

The French Starlette satellite (6 February 1975) was the first of a series of international geodetic satellites based on relatively simple spherical platforms embedded with laser reflectors and was followed by Lageos (US-1976), EGS (Japan-1986), Etalon (USSR-1989), and LAGEOS 2 (Italy-1992). The 47-kg Starlette is 26 cm in diameter, circles the Earth in an orbit of 800 km by 1,100 km at an inclination of 49.8°, and carries 60 laser reflectors evenly distributed about its surface. On 26 September 1993 Starlette was joined by the French Stella satellite of similar design. Stella accompanied the SPOT 3 satellite into a 795 km by 805 km, 98.7°-inclination orbit where it will enable geodetic measurements to be expanded into the polar regions. The Stella program is being managed by CNES and ONERA (Office National d'Etudes et de Recherches Aérospatiales).

During 1966-1975 France launched five other satellites with dedicated or auxiliary geodetic missions. Diapason (1966) was an active, 19-kg satellite with 149.70 and 399.92 MHz transmitters to permit geodetic measurements based on doppler techniques and is no longer operational. Diademe 1 and Diademe 2 were launched one week apart in February, 1967, into elliptical orbits (currently, 550 km by 1,100 km and 600 km by 1,700 km, respectively) at an inclination of 40°. In addition to dual-frequency transmitters like Diapason, the 22.6 kg Diademe spacecraft were also covered with numerous laser reflectors. Two other spacecraft also carried laser reflectors, Peole (1970) and Castor (1975), but both have since decayed.

#### **4.2.3 Germany**

In May, 1994, the German firm GeoForschungsZentrum (GFZ) Potsdam signed a contract with Kayser-Threde GmbH "for the design, construction and launch of a small Earth-Science Research Satellite" (Reference 425). The 20-kg, 20-cm-diameter satellite, called GFZ-1, will be delivered to the Mir space station in 1995 by a Progress-M spacecraft and later released at an altitude of about 400 km. During its natu-

ral decay, the passive, spherical satellite equipped with multiple laser reflectors will be used for a variety of geodetic studies. Russian engineers will be responsible for the construction of the satellite, including the laser reflectors. Laser ranging systems in Germany and Cuba will comprise the principal data collection network. GFZ-1 is expected to remain in Earth orbit for up to five years.

#### **4.2.4 INMARSAT**

The INMARSAT organization has decided to extend its telecommunications services to navigational aids with the launch of its INMARSAT 3 series spacecraft, beginning in 1995. The objective is to increase the accuracy of the American GPS and the Russian GLONASS systems by "relaying ionospheric calibration and differential corrections to the GPS and GLONASS signals; providing additional ranging signals to increase GPS availability worldwide; relaying ground-derived GPS and GLONASS integrity information. . ." (Reference 425). Feasibility tests have already been conducted with operational INMARSAT 2 spacecraft. Opposition to the system has been voiced by the US Department of Defense due to the system's potential of increasing the accuracy of GPS signals via differential corrections below the 100-m level set for civil use (References 426-427).

INMARSAT is also considering more direct methods of furnishing precision navigation information to users world-wide. One option foresees placing navigation packages on up to 15 GEO spacecraft as secondary payloads. Each of these packages would transmit GPS-class navigation signals to form an independent network. Other alternatives include placing similar packages on INMARSAT's proposed INMARSAT-P spacecraft in orbits near 10,000 km altitude or establishing an autonomous navigation system with dedicated spacecraft, possibly deployed in both intermediate and geosynchronous orbits (Reference 426).

#### **4.2.5 Italy**

Italy's first and only geodetic satellite was launched in 1992 with the aid of the US. LAGEOS 2, built by Aeritalia Space Systems Group, is a twin to the US' LAGEOS satellite launched in May, 1976, with a mass of 405 kg, a diameter of 60 cm, and a total of 426 laser reflectors. Deployed from the US Space Shuttle Columbia (STS-52), LAGEOS 2 was boosted

into an orbit of approximately 5,615 km by 5,950 km at an inclination of  $52.7^\circ$  by an Italian-made IRIS upper stage.

The orbital altitude is almost identical to that of LAGEOS, but the lower inclination of LAGEOS 2 compared with LAGEOS ( $52.7^\circ$  versus  $109.9^\circ$ ) will permit better understanding of the Earth's gravitational field and will enhance observations from European latitudes. Together, the two satellites will provide data capable of detecting tectonic movements on the order of 2 cm per year (References 428-430). The launch of LAGEOS 2 was delayed several years due to the US Challenger accident.

#### 4.2.6 Japan

The success of the US and French geodetic satellites launched in the mid-1970's influenced Japan's national space agency, NASDA, to sponsor a similar, yet complementary, geodetic satellite. Under the auspices of the Hydrography Department of the Maritime Safety Agency and the Geographical Survey Institute of the Ministry of Construction, the objectives of the Experimental Geodetic Satellite (EGS, also known as Ajisa) are to:

- correct the geodetic triangulation nets in the country,
- determine the location of isolated islands (improve the marine geodetic network) and
- establish Japan's geodetic datum" (Reference 431).

EGS was launched 12 August 1986 on the inaugural mission of the H-I launch vehicle. The 685 kg satellite is spherical with a diameter of 2.15 m, but, unlike other geodetic satellites of its class, EGS is covered with both laser reflector assemblies (120 with 1436 corner cubes) and solar reflecting mirrors (318). The mean altitude of EGS is slightly less than 1,500 km with an orbital inclination of  $50.0^\circ$  (Reference 432).

#### 4.2.7 People's Republic of China

Although the PRC has yet to establish a navigation satellite network, research for such a system has been underway for many years, and a future space-based navigation capability is an acknowledged goal. A prototype navigation satellite was built by the early 1980's but was never launched. In appearance the spacecraft resembles the Shi Jian 2 scientific satellite launched on 19 September 1987. This spacecraft bus is octagonal with a diameter of 1.2 m

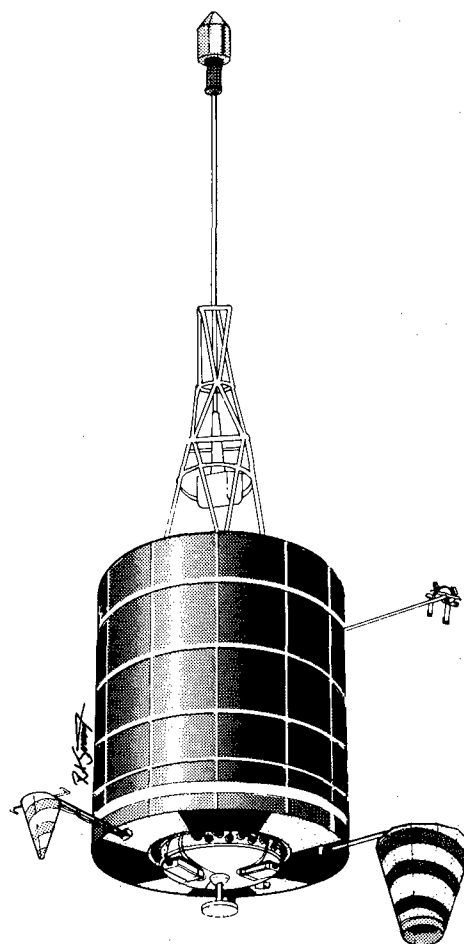


FIGURE 4.55 NEDEZHDA SATELLITE.

and a height of 1 m with a mass of about 250 kg, including the payload. The navigation system was possibly of the US Transit and Russian Tsikada class (References 433-434). More recent writings have indicated a desire to deploy navigation satellites by the end of the decade (References 435-437). A hand-held receiver compatible with US GPS satellites, the VT 900, has already been developed by the Chinese Carrier Rocket Technology Institute (Reference 438).

#### 4.2.8 Russian Federation

Twelve percent of Russia's orbital missions during 1993-1994 were devoted to the fields of navigation and geodesy, bringing to more than 150 the number of Soviet/Russian navigation and geodetic spacecraft placed into Earth orbit since 1967. By the end of 1994, the Russian navigation satellite network consisted of 25 principal spacecraft in three distinct constellations to service both fixed and mobile subscri-

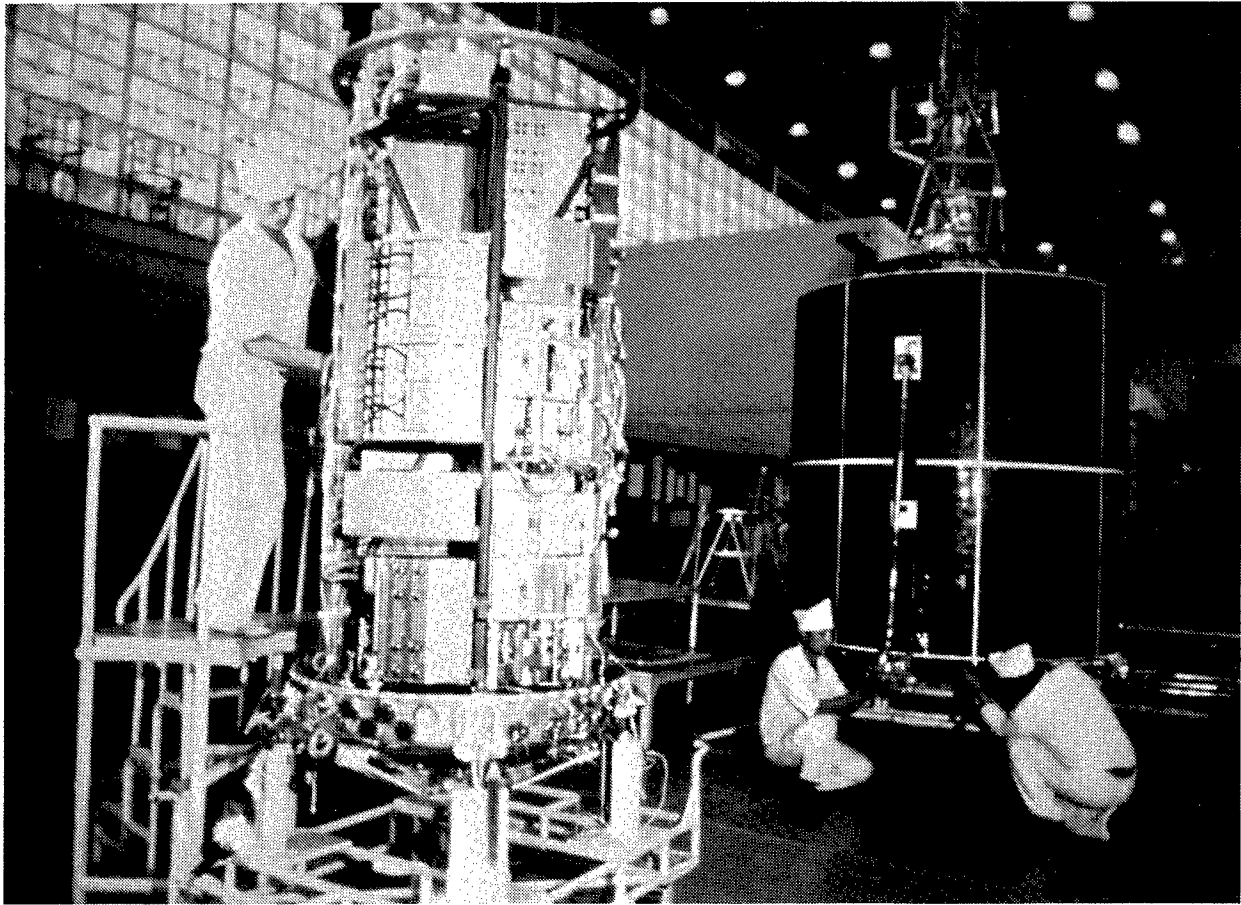


FIGURE 4.56 TSIKADA SATELLITE IN ASSEMBLY.

ers. The geodetic network, on the other hand, includes only 1-2 active spacecraft, two specialized laser reflector satellites, and a larger number of host spacecraft carrying small laser reflectors.

The LEO navigation satellites are launched one at a time by Kosmos boosters from the Plesetsk Cosmodrome into orbits of approximately 960 km by 1,015 km with an inclination of 83°. Each spacecraft has a diameter of 2 m, a height of approximately 3 m and a mass of 800 kg. An internally pressurized compartment housing the primary payload (approximately 0.86 m in diameter, 0.55 m in height, mass of 200 kg) and support systems is surrounded by solar cells affixed to a cylindrical sheet. Electrical power available to the payload is limited to about 200 W average daily (References 439-440). Attitude control is achieved with a 10-m gravity-gradient boom extending from the top of the spacecraft, while payload and telemetry antennas are attached to the bottom, Earth-facing end (Figures 4.55 and 4.56).

Navigation information is derived from Doppler-shifted VHF transmissions (approximately 150 and 400 MHz) of satellite position and orbital data (References 441-442). By acquiring fixes from several satellites, a user's location can be calculated with an accuracy of 100 m (Reference 443). The time needed to ascertain one's position is dependent upon the user's latitude and the number of operational spacecraft in orbit. Normally, ten first-generation Russian satellites are transmitting navigational signals, permitting accurate location determination within 1-2 hours.

These ten spacecraft are deployed in two complementary constellations. The older constellation (first launch in 1974 with Kosmos 700) consists of six satellites distributed in orbital planes spaced 30° apart. This network with Parus satellites (aka Tsikada-M) is never explicitly referred to by Russian officials and is primarily dedicated to the support of military forces. A virtually identical civilian navigation network, called Tsikada, began deployments in 1976 with

Kosmos 883 and employs four orbital planes separated by 45°. Moreover, the Tsikada orbital planes are carefully offset from the military satellites to maximize consolidated system effectiveness, i.e., minimize the mean time between satellite sightings. The Tsikada system is widely used by the Russian merchant marine which is equipped with Shkhuna receiving equipment which automatically computes the vessel's position. Originally, designed and manufactured by the Applied Mechanics NPO in Krasnoyarsk, both type of navigation satellites are now largely produced by the Polet PO in Omsk, where an annual production rate of ten spacecraft has been achieved. The navigational payloads were developed, in part, by the Institute of Space Device Engineering. By the end of 1994 more than 130 first generation satellites had been launched — an average of five per year since

1967.

Despite their obvious similarities, Parus military navigation satellites are replaced at a much faster rate - about twice as often - than their Tsikada civilian cousins. During 1993-1994 two-thirds of the Parus network was replenished. Kosmos 2233 (9 February 1993) replaced Kosmos 2142 after 22 months in space, and Kosmos 2239 (1 April 1993) relieved Kosmos 2173 which had been on duty only 16 months. Later in the year according to Kettering Group observations, Kosmos 2195 failed after a little more than a year and was removed from the network. Its predecessor, Kosmos 2135, was then reactivated in early August while a replacement satellite was prepared. Finally, on 2 November Kosmos 2266 was launched to assume the No. 1 Parus position. The only Parus satellite launched in 1994 was Kosmos

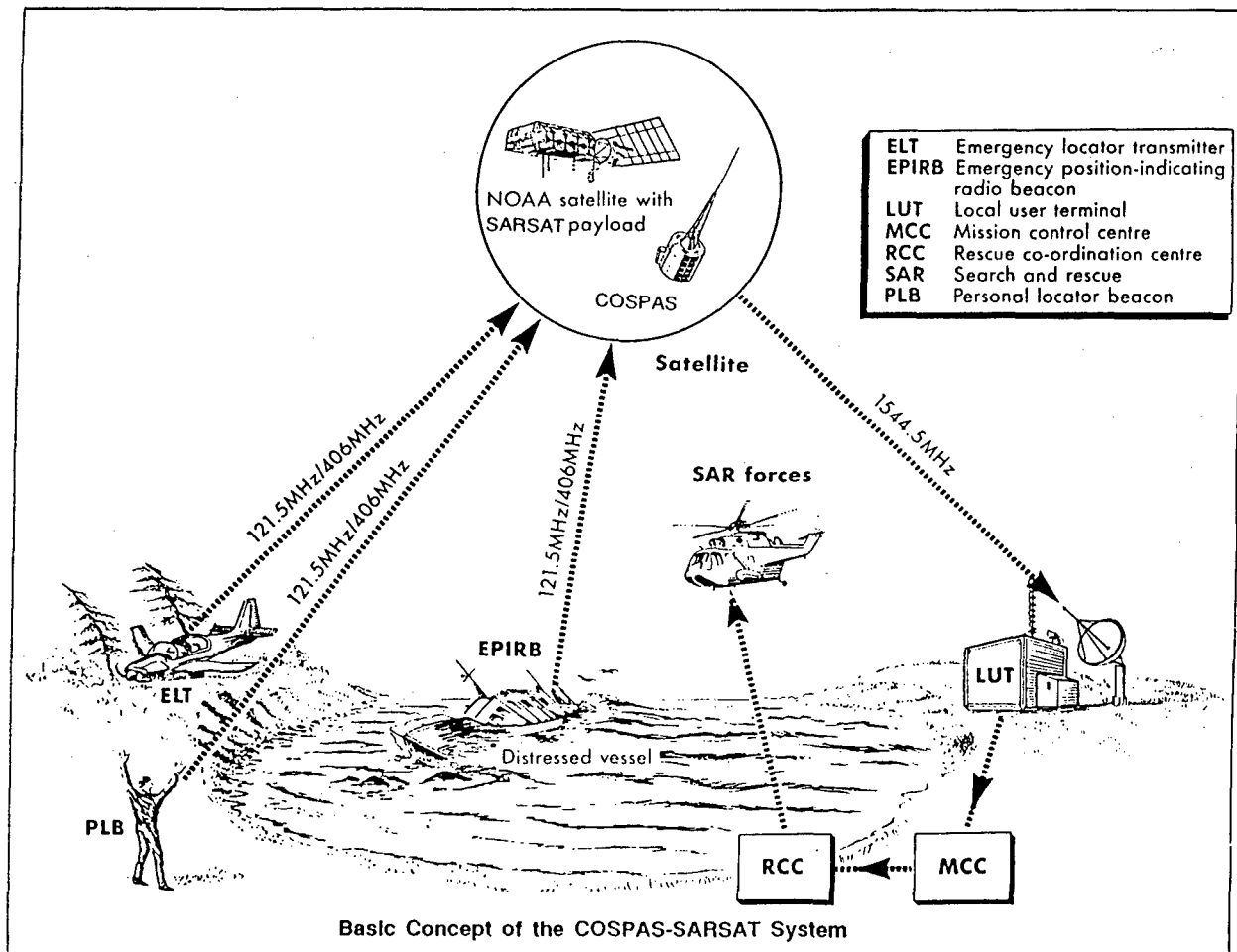


FIGURE 4.57 INTERNATIONAL COSPAS/SARSAT SYSTEM.

2279 on 26 April to replace the 26-month-old Kosmos 2180.

In the Tsikada system, two of the four active satellites were replaced. Surprisingly, Kosmos 2230 was launched on 14 January into the same orbital plane as Kosmos 2181, which had been the youngest Tsikada spacecraft with only 10 months in orbit. The next launch did not come for 18 months when Nadezhda 4 replaced the 4-year-old Nadezhda 2. The Nadezhda (Hope) name is now used whenever a Tsikada satellite carries a special transponder for use by the international COSPAS-SARSAT system for search and rescue of airmen and seamen in distress.

Established in principle by the USSR, US, Canada, and France in 1979, COSPAS-SARSAT is designed to relay distress signals from the site of aircraft and ship accidents or other emergency situations to special Local User Terminals (LUTs) which in turn notify the appropriate search and rescue teams (Figure 4.57). Distress signals are transmitted on either 121.5 MHz (15 km location accuracy) or 406 MHz (2 km location accuracy) and rebroadcast on 1544.5 MHz to LUTs. Over 600,000 beacons are deployed worldwide, saving more than 4,500 lives since the system began operations via Kosmos 1383 in September, 1982. The number of deployed beacons could double by the end of 1995 (References 444-445).

The Ukrainian Musson Corporation of Sevastopol has been the primary supplier of COSPAS distress beacons for the Russian Federation. The ARB (Emergency Locator Beacon) - 121 system employs the 2.2 kg Poisk-B emergency locator beacon and the 1.8 kg Poisk-R emergency distress signal transmitters for the COSPAS lower band, while the more popular 4.5 kg ARB-406 emits the higher frequency distress signal every 50 seconds for up to 48 hours with a power of 5 W (Reference 131). Veteran cosmonaut G. S. Titov is now President of a new Russian firm called Kosmoflot which will also manufacture navigational equipment and COSPAS beacons. The primary Russian LUTs are located at Arkhangelsk, Moscow, Novosibirsk, and Vladivostok. The Russian Federation has also proposed the creation of a rocket-borne rescue system called VITA which would employ converted SS-18 or SS-19 ICBM's to send rescue equipment to the site of an accident identified by the COSPAS-SARSAT system (Section 2.9).

Whereas the Soviet low altitude navigation systems were patterned after the American Transit network, a Soviet counterpart to the US Global Positioning System first appeared in 1982, four years after the launch of the first Navstar GPS satellite. The now Russian Military Space Forces' Global Navigation Satellite System (GLONASS) is designed to provide instantaneous, high precision location and speed information to users throughout most of the world. Deployed in nearly circular orbits at an altitude of 19,100 km by Proton boosters, each GLONASS satellite emits navigational signals in a 38° degree cone near 1250 MHz (L2). GLONASS positional accuracies (95% confidence) are claimed to be 100 m on the surface of the Earth, 150 m in altitude, and 15 cm/s in velocity.

Like Tsikada, GLONASS spacecraft were developed under the leadership of the Applied Mechanics NPO with the assistance of the Institute for Space Device Engineering. A third party, the Russian Institute of Radionavigation and Time, has been responsible for time synchronization and related equipment. Also following the Tsikada precedent, serial production for GLONASS satellites has been accomplished primarily by the Polet PO. Conceived and promoted in the early 1970's by the former Soviet Ministry of Defense, and in particular by the Soviet Navy, GLONASS is now the centerpiece of the CIS' Intergovernmental Radionavigation Program, which has close ties with the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) (References 446-458).

By Presidential decree on 24 September 1993, just before the 11th anniversary of the maiden GLONASS mission, the GLONASS program was officially placed under the auspices of the Russian VKS. This organization is responsible not only for the deployment and on-orbit maintenance of GLONASS spacecraft (the latter through the Golitsino-2 Satellite Control Center) but also, through its Scientific Information Center, for certification of GLONASS user equipment.

Since the program began deployments in 1982, four models of GLONASS spacecraft have been flown. Ten Block I satellites were launched during 1982-1985 with design lifetimes of only one year (average actual lifetime of 14 months). Six Block IIa satellites followed in 1985-1986 with new time and frequency standards and increased frequency stability. The

Block IIa spacecraft also demonstrated a 20% increase in operational lifetime.

Block IIb spacecraft with 2-year design lifetimes appeared in 1987, and a total of 12 were launched, but half were lost in launch vehicle accidents. The remaining spacecraft worked well, operating for an average of nearly 22 months each. The current GLONASS model, Block IIv, has been in use since 1988 with 12 of the 34 satellites launched during 1993-1994. One Block IIv spacecraft, which are expected to operate for at least three years, worked for 50 months before being placed in a standby status.

The 3-axis-stabilized GLONASS spacecraft (Figure 4.58) now possess a mass of about 1,400 kg, a slight increase over the 1,250-kg original model. The diameter and height of the satellite bus are approximately 2.4 m and 3.7 m, respectively, with a solar array span of 7.2 m for an electrical power generation capability of 1.6 kW at beginning of life. The aft payload structure houses 12 primary antennas for L-band transmissions. Laser corner-cube reflectors are also carried to aid in precise orbit determination and geodetic research. GLONASS spacecraft are equipped with a modest propulsion system to permit relocation within the constellation and to maintain interplane phasings.

The Phase I GLONASS system was completed in 1991 with seven active satellites in each of two orbital planes separated by  $120^\circ$ . (The official Phase I goal was six satellites in each of two planes.) Within each plane the spacecraft are spaced  $45^\circ$  apart with a  $15^\circ$  phase shift between planes. The Phase II requirement for seven active and one spare satellite in each of three orbital planes separated by  $120^\circ$  is scheduled to be met by 1995.

The two principal GLONASS receivers are the SNS-85 for airborne platforms and the Shkiper for naval vessels. The former unit has a mass of only 13.5 kg and dimensions of 201 x 259 x 364 mm, while the latter is somewhat larger at 21.5 kg and 263 x 425 x 426 mm. However, the Shkiper provides a more accurate velocity determination: 15 cm/s compared to 50 cm/s for the SNS-85. The similarity of the GLONASS and GPS frequencies and techniques permits the creation of single, dual-use receivers when the slightly different geodetic (e.g., SGS-85 versus WGS-84, respectively) and time reference frames are taken into account. Such a dual-use receiver has been developed by the Institute of Space Device Engineering. Several

concepts have been proposed for integrating the GLONASS and GPS networks, particularly for international civil aviation (References 459-469).

A total of 12 GLONASS spacecraft were added to the network during 1993-1994 with four launches of three vehicles each: Kosmos 2234-2236 in 1993 and Kosmos 2275-2277, 2287-2289, and 2294-2296 in 1994. The Kosmos 2287-2288 mission was particularly noteworthy with its inauguration of the GLONASS Plane 2. By the end of 1994, 15 GLONASS spacecraft remained operational (Figure 4.59), although Kosmos 2111 in Plane 1 was in a non-nominal position due to a propulsion system failure early in life. During October, 1993, Kosmos 2206 transferred from slot 20 to slot 21 which was then occupied by Kosmos 2205 which had been moved from slot 18.

While GLONASS is scheduled to reach full operational capability in 1995, the first flight of the improved GLONASS-M Block I spacecraft is anticipated in 1995-1996. Under development since 1990, the 1,480 kg satellite will feature better frequency and timing accuracies as well as an extended operational life of 5-7 years. Further in the future, perhaps after the turn of the century, a 2,000-kg-class GLONASS-M Block II may be available with intersatellite communications and monitoring and capable of autonomous operations for as long as 60 days (References 470-472).

Within a few years of the debut of GLONASS satellites, the world scientific community, in particular radio astronomers, discovered a harmful side-effect of the system. The heart of the GLONASS L1 band coincides with the weak natural emissions of extra-solar hydroxyl molecules. Consequently, some spacecraft transmissions were interfering with radio astronomy

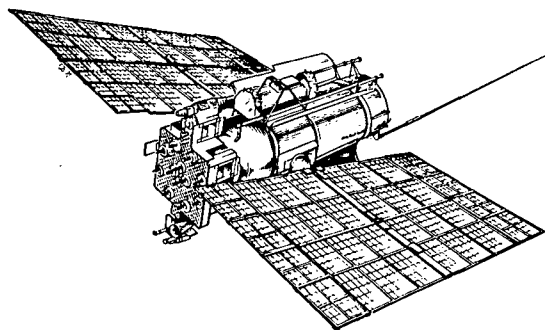


FIGURE 4.58 GLONASS SATELLITE.



surveys. As the number of operational GLONASS spacecraft increased, the problem became severe and was further accentuated by the fact that the high altitude satellites remain above the horizon for extended periods. However, having been made aware of the problem, the GLONASS program is incorporating measures to minimize the interferences (References 473-476).

Dedicated geodetic satellites have been in use by the USSR/CIS since 1968 (Kosmos 203). Extremely precise knowledge of the topography and gravitational field of the Earth is of great importance to the civilian as well as to the military community. However, only since 1989 have specific details of the Russian programs been made available. Today, two different satellite networks, one low altitude and one high altitude, are available for geodetic studies.

The current LEO geodetic system, known as GEO-IK, is a second generation design which debuted in 1981 and has averaged one new launch each year of the Musson class satellites. With normally one or two satellites operational, the GEO-IK network can assist the user in

- creating of regional geodetic nets, including:
  - islands geodetic fixation
  - basis for topographic survey of large building objects

- geodetic basis for working onto shelf of the World Ocean

- working by request of coordinate fixation of the points in required coordinate system
- working to research the topography of the World Ocean" (Reference 447).

GEO-IK satellites are deployed in nearly circular orbits with a mean altitude of 1,500 km at inclinations of 73.6° or 82.6°. (Since 1986 only the former inclination has been utilized.) Each spacecraft is launched by the Tsyklon-3 booster from the Plesetsk Cosmodrome. The Applied Mechanics NPO of Krasnoyarsk is the principal designer and manufacturer of the 1,500-kg GEO-IK. The satellite bus is similar in appearance to the Tsikada navigation satellites, i.e., primarily a right cylinder with a gravity-gradient stabilization system at the top and payload antennas, etc., attached to the bottom (Figure 4.60). However, eight panels extend like petals from the bottom of the spacecraft to provide additional electrical power in conjunction with nickel-hydrogen storage cells. Also like Tsikada, payload and support systems are primarily contained within a pressurized, temperature-controlled container located inside the cylindrical, solar-cell array.

Geodetic analyses can be performed with any one of five payload systems. A 9.4 GHz radar provides altitude determination above the sea surface with an accuracy of 3-5 m. A two-

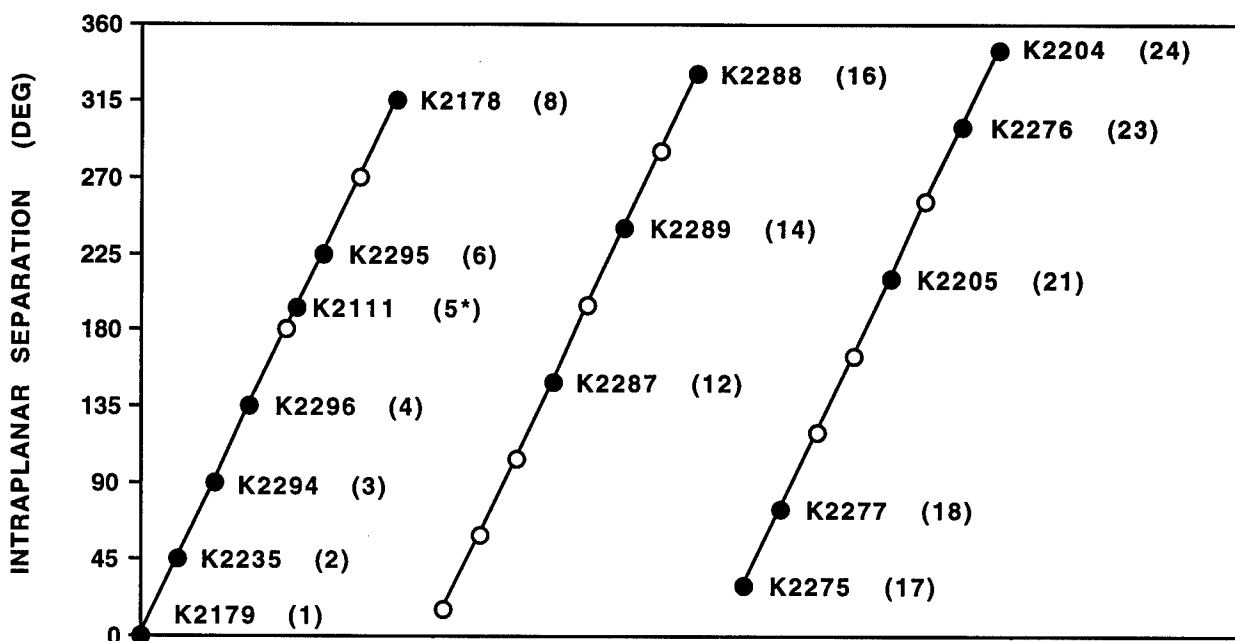


FIGURE 4.59 STATUS OF GLONASS CONSTELLATION, 31 DECEMBER 1994.

frequency (150 MHz and 400 MHz) doppler system (1-3 cm/s accuracy) operates up to 12 hours per day, and a 5.7/3.4 GHz transponder is also available on demand to provide ranging data to within 3-5 m. Laser corner reflectors with a total area of 0.024 m<sup>2</sup> are installed on the spacecraft permitting range determinations to within 1.5 m. Finally, a light signaling system producing a series of nine high intensity (800-1200 J) flashes at a rate of 1/3 Hz can be used in conjunction with ground-based observatories to determine the satellite's position against the star background to within 1.5 arc seconds. The light signaling system can be activated up to 55 times per day (References 477-482).

Normally, GEO-IK geodetic measurements are performed five days per week, permitting two days of mission planning and satellite position forecast preparation. Typical spacecraft lifetimes are only 1-2 years. The principal civilian processor of and clearinghouse for geodetic data is now the Russian Ministry of Ecology and National Resources (which absorbed the former Soviet Main Administration for Geodesy and Cartography), working in conjunction with the Russian Academy of Sciences, in particular the Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (IZMIRAN).

The 14th Musson satellite was launched on 29 November 1994 (the first was lost in a launch failure on 23 January 1981) and was the first to be officially designated GEO-IK rather than Kosmos. GEO-IK 1 was inserted into a 73.6° orbit like the three previous spacecraft of this series. Moreover, the newcomer's orbital plane was approximately 60° to the east of its immediate predecessor, also a pattern followed since 1989. As noted in Section 4.1.22, GEO-IK 1 carried as an auxiliary package the Elekon communications test transponder.

In contrast to GEO-IK, the Russian Etalon satellites reside in high altitude (19,100 km) orbits and are completely passive in nature. Each 1,415-kg satellite is a 1.294 m diameter sphere covered with 306 antenna arrays which in turn each contain 14 corner cubes for laser interrogation and reflecting (Figure 4.61). A small number of reflectors are made of germanium for "future infrared interferometric measurements" (Reference 483). To date only two Etalon satellites have been orbited, Kosmos 1989 (10 January 1989) and Kosmos 2024 (31

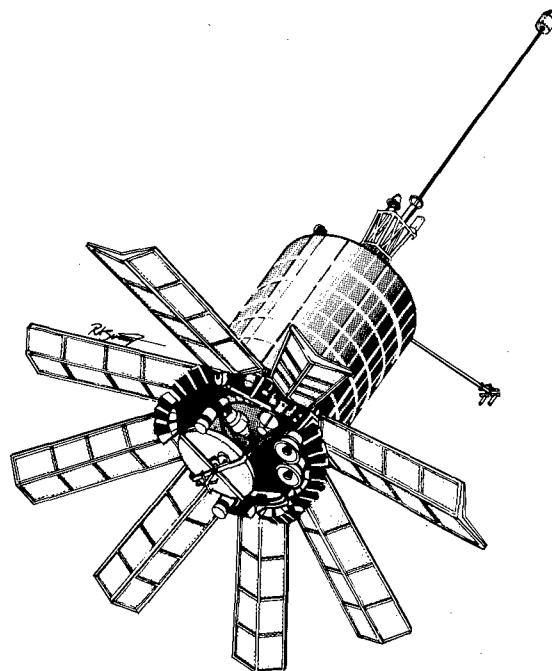


FIGURE 4.60 GEO-IK SATELLITE.

May 1989), and each accompanied a pair of GLONASS satellites on Proton launch vehicles.

The higher altitude of the Etalon satellites, when compared to similar laser-reflecting geodetic satellites of other nations, was selected to enhance several specific goals: "(1) the development of a high-accuracy global reference coordinate system and determination of the Earth's rotation parameters, (2) determination of lengths of long baselines, (3) improvement of the Earth's gravitational field parameters, and (4) improvement of the selenocentric gravitational constant" (Reference 483). The effect of non-gravitational forces on the orbits of the Etalon satellites was reported in late 1990 and further studies, including the effects of the Sun and the planets, were released in late 1993 (References 484-486).

#### 4.3 EARTH OBSERVATION AND REMOTE SENSING

Although unmanned observations of the Earth from artificial satellites have been conducted for more than three decades, the growing international concern about the global environment has led to a renewed emphasis on the monitoring of the planet's land masses and oceans as well as the atmosphere. Moreover, recent satellite systems and those now in devel-

opment possess a much wider variety of more sophisticated instruments. Whereas national Earth observation programs have historically concentrated on atmospheric and meteorological data collection, today both passive and active techniques are employed to keep watch over virtually all aspects of the environment. An unprecedented degree of international cooperation and standardization, particularly in data transmission, permits a free exchange of information and at times even asset sharing. A total of 18 dedicated Earth observation spacecraft were launched during 1993-1994 under the sponsorship of seven Eurasian nations or organizations.

#### 4.3.1 European Space Agency

With its emphasis on commercial and scientific space activities, ESA has historically not devoted major resources to satellite applications programs. The principal exceptions to this rule have been the geostationary Meteosat (since 1977) and the sun-synchronous European Remote Sensing (ERS, since 1991) satellite programs. In part due to the impressive successes of these programs, ESA at its 1991 and 1992 ministerial meetings elevated the organization's commitment to Earth observation networks. Consequently, both current systems will be upgraded or superseded in the second half of this decade with yet more capable spacecraft.

In conjunction with the Global Atmospheric Research Program (GARP), ESA developed

and maintains geostationary meteorological satellites of the Meteosat series. Three pre-operational spacecraft were launched in 1977, 1981, and 1988, respectively, before the Meteosat Operational Program (MOP) was initiated with the orbiting of Meteosat 4 in 1989. Although ESA originated and continues to control the Meteosat network, the 16-member European Organization for Meteorological Satellites (EUMETSAT), created during 1981-1986, is now responsible for the system. Beginning with Meteosat 4, EUMETSAT is the legal owner of the series satellites.

Meteosat satellites closely resemble their American and Japanese counterparts. Each spacecraft has a mass of about 320 kg on station in the form of a 2.1-m-wide, 3-m-tall, spin-stabilized (100 rpm) stepped cylinder (Figure 4.62). Solar cells cover the majority of the spacecraft surface providing a minimum of 200 W of electrical power. The satellite design life is three years with consumable supplies for at least five years. The prime contractor for Meteosat is the French firm Aerospatiale with major subcontractors DASA, Matra Marconi, and Alenia Spazio.

The primary Meteosat payload is a 40-cm diameter, 3-band, imaging radiometer sensitive to visible light (0.5-0.9  $\mu\text{m}$ ), IR (10.5-12.5  $\mu\text{m}$ ), and water vapor (5.7-7.1  $\mu\text{m}$ ). Resolution for the visible band is 2.5 km, while that for the other two bands is 5 km. A single image requires a scan time of 25 minutes with a limit of 48 images per day. Meteosat also carries a 66-channel capacity data collection service package to receive local environmental information. Data collection platform reports from 4,000 sites are forwarded by Meteosat to the primary control center at Odenwald, near Darmstadt, Germany, for further distribution (References 487-492).

In early 1993, the operational Meteosat constellation consisted of three spacecraft: Meteosat 3 (aka Meteosat P2) near 75° W, Meteosat 4 (aka MOP 1) near 0° E, and Meteosat 5 (aka MOP 2) near 4° W. Meteosat 3 had just arrived at its far Western Hemisphere location in February to assist the US which was experiencing difficulties with its own GOES (Geostationary Operational Environmental Satellite) system and remained there through the end of 1994 (References 491 and 493).

Meteosat 4, despite some imaging difficulties encountered early in life (launched in June,

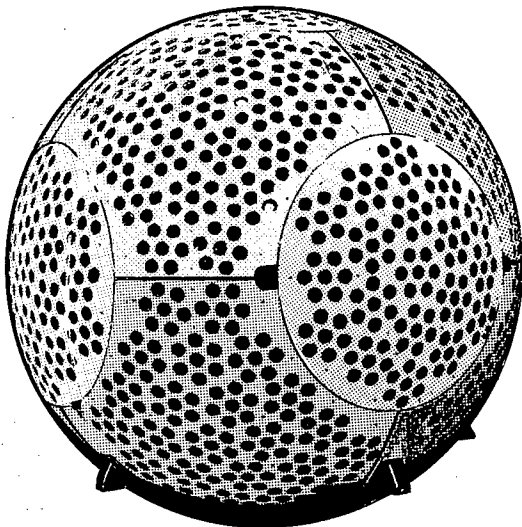


FIGURE 4.61 ETALON SATELLITE.

1989), was serving as the Meteosat prime spacecraft since its planned replacement, Meteosat 5, was having more serious imaging problems of its own. The launch of Meteosat 6 (aka MOP 3) on 20 November 1993 by Ariane was to help remedy the situation by replacing Meteosat 4 and allowing Meteosat 5 to relieve Meteosat 3. However, Meteosat 6's IR radiometer experienced malfunctions from the outset. The decision was then made to move Meteosat 5 into the prime location at 0° E in February, 1994, and place Meteosat 4 in standby at 8° W. Meanwhile, Meteosat 6 was left at 10° W to permit the development of corrective measures for the radiometer problem (References 494-499).

The next Meteosat, scheduled for launch in mid-1996, will support the Meteosat Transition Program (MTP), which encompasses major programmatic as well as technical changes. At the end of 1995, EUMETSAT will take full responsibility of the MOP and MTP spacecraft from ESA. At the same time, development of the Meteosat Second Generation (MSG) is underway with an anticipated maiden launch about the year 2000. ESA will supervise the production of the first MSG vehicle and then turn the entire program over to EUMETSAT. Each MSG spacecraft will have increased wavelength fidelity (up to 12 bands), better resolution (as low as 1 km), more rapid imaging (15 min per full scan), and greater spacecraft longevity (at least twice that of MOP satellites). Phase B activities for MSG, which will look very similar to MOP but be twice as large, got underway in 1994 with joint funding from ESA and EUMETSAT (Reference 499).

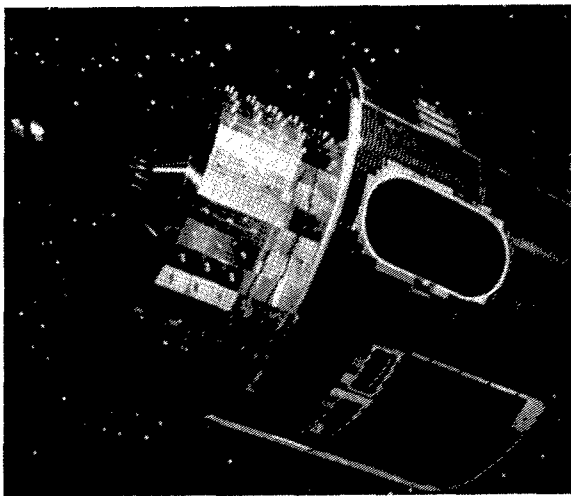


FIGURE 4.62 METEOSAT SATELLITE.

ESA's low altitude Earth observation system debuted in 1991 with the launch of ERS-1. The culmination of a 10-year development project led by Germany, ERS-1 hosts a suite of precision instruments tailored for a comprehensive environmental monitoring program with objectives including:

- a much more accurate representation of the interactions between ocean and atmosphere in climatic models,
- a major advance in our knowledge of ocean circulation, its variability and the associated energy transfers,
- better monitoring of polar regions, in particular the Arctic and Antarctic ice sheets and sea-ice-covered areas,
- a more comprehensive understanding of coastal processes and surface pollution, including erosion, sedimentation, coastal currents, estuarine fronts and circulation,
- the regular monitoring of land-surface processes on a global scale, and in particular the vegetation cover,
- the monitoring of changing land-use patterns,
- offering a unique all-weather sensing capability for disaster observation and assessment, and
- enhancing the data available for operational meteorology, in particular observation of winds near the sea surface, sea-state, sea-surface temperature measurements, cloud fields, atmospheric water content, and sea-ice distribution" (Reference 500).

The 2,384-kg ERS-1 satellite employs a spacecraft bus derived from the French SPOT satellite, measuring 1.8 m by 1.9 m by 3.1 m (Figure 4.63). The two primary appendages are a solar array with two 2.4 m by 5.8 m segments providing more than 2 kW of electrical power and a combination radar antenna for the Active Microwave Instrument. Placed into a sun-synchronous orbit near 780 km with an inclination of 98.5°, ERS-1 carried 300 kg of hydrazine for a mission expected to last three years. The spacecraft's orbit is maintained with a very high degree of accuracy, resulting in a 35-day groundtrack pattern which is controlled within  $\pm 1$  km (References 501-502).

The five principal scientific instruments include:

- (1) Active Microwave Instrument (AMI) consisting of a side-locking synthetic aperture radar and a scatterometer, both

operating at 3.5 GHz. The former returns high resolution photographs with a 100 km ground swath in the image mode or 5 km by 5 km snapshots in the wave mode. With the use of three antennas with 45° separation angles, the scatterometer sweeps a 500 km swath to provide surface wind measurements;

- (2) Radar Altimeter (RA) with separate "ocean" and "ice" modes operating at 13.8 GHz;
- (3) Along-Track Scanning Radiometer (ATSR) and Microwave Sounder (MS) consisting of an Infrared Radiometer and a Microwave Radiometer to measure the global sea-surface temperature and the atmospheric integrated water content, respectively. The Infrared Radiometer operates at the 1.6, 3.7, 11, and 12  $\mu\text{m}$  bands, while the Microwave Radiometer is tuned to 23.8 and 36.5 GHz;
- (4) Laser Retro-Reflector (LRR) assembly of corner cubes mounted on the side of the spacecraft bus is used as a target by ground-based laser ranging stations;
- (5) Precise Range and Range-rate Equipment (PRARE) utilizes 2.2 GHz and 8.5 GHz transmissions for ionospheric corrections and orbit determination, respectively.

Despite some early data distribution difficulties, ERS-1 has performed remarkably well, returning nearly 800,000 radar images in its first three years of operation alone. The AMI images of ocean areas have been of higher quality than expected, and the uses of ERS-1 data - from oil spill detection to salmon tracking - continue to increase. The most serious technical setbacks of the mission were the failures of PRARE less than a month after launch and one channel of the ATSR. However, the greatest threat to ERS-1 has been continued wrangling over its annual operating budget. A potential 1994 shut-down was averted, and the program was eventually extended to permit simultaneous operations with ERS-2, scheduled for launch in 1995 (References 503-516).

ERS-2 (Figure 4.64) will resemble its predecessor but will be equipped with a broader array of instruments and more modern support systems. The 2,516-kg spacecraft will retain the 1 m-by-10 m SAR antenna and its 2.4 m-by-11.7

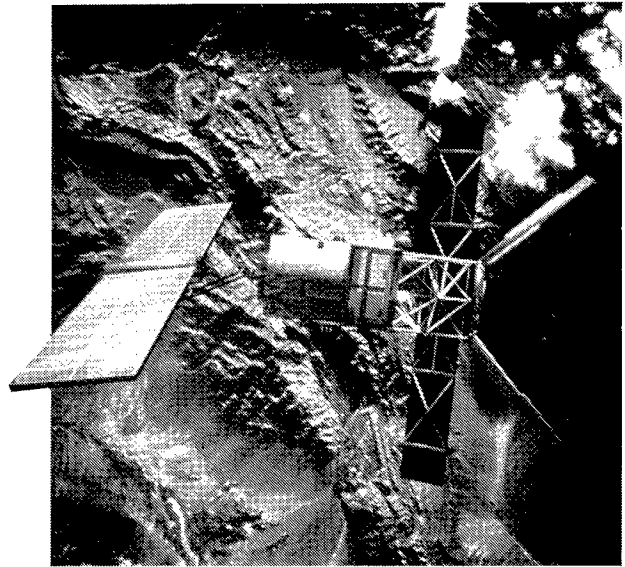


FIGURE 4.63 ERS-1 SATELLITE.

m solar array. In addition to reflights of all the basic ERS-1 payloads, ERS-2 will carry the Global Ozone Monitoring Experiment (GOME) with an absorption spectrometer to measure the presence of ozone, trace gases, and aerosols in the stratosphere and troposphere and an Instrument Data Handling and Transmission (IDHT) device with two 6.5 GBit tape recorders (References 506 and 517).

The November, 1992, ESA ministerial meeting (Reference 518) reaffirmed the organization's intention to follow the ERS program with the ambitious Polar-Orbiting Earth Observation Mission (POEM), which was separated into two distinct projects: Envisat-1 and Metop-1. The former, based on an 8-metric-ton Polar Platform bus, will be launched in 1998-1999 into an 800-km altitude, sun-synchronous orbit to understand and to monitor better the Earth's environment and to continue the SAR surveys of the ERS spacecraft. France and the UK will each fund about one-fourth of the Envisat mission with other ESA members pooling resources for the remaining half.

With a spacecraft bus measuring 2.75 m in diameter and 11 m long, Envisat-1 will carry a useful payload of about 2,000 kg, including five ESA-funded instruments: an advanced synthetic aperture radar, an advanced radar altimeter, a medium resolution imaging spectrometer, a Michelson interferometer for passive atmospheric sounding, and a global ozone monitor (Figure 4.65). National sensors expected to be carried by Envisat-2 include a French radiome-

ter (SCARAB), a German imaging spectrometer (SCIAMACHY), and a British-Australian radiometer (AATSR). A microwave sounder, similar to the ones developed for ERS, will also be installed. The spacecraft's orbit will be essentially the same as used in the ERS program, and the 6.6 kW electrical system will provide nearly 2 kW to the instrument suite (References 499, 519-526).

The second component of the POEM program, Metop-1, will be launched in the year 2000 and will provide ESA and EUMETSAT with their first low altitude, polar meteorological satellite. The Metop design completed Phase A definition in 1994 and was to rely on the basic Polar Platform bus being developed for Envisat-1. However, a substantially smaller Metop-1, perhaps in the 2,500-kg class, is now likely. The Phase B contract award was anticipated in the first half of 1995. While payload definition for Metop-1 is still underway, the instrument suite will contain a large variety of visible, IR, and microwave radiometers, ozone monitors, and probably an advanced wind scatterometer. A plan to merge Metop operations with US NOAA

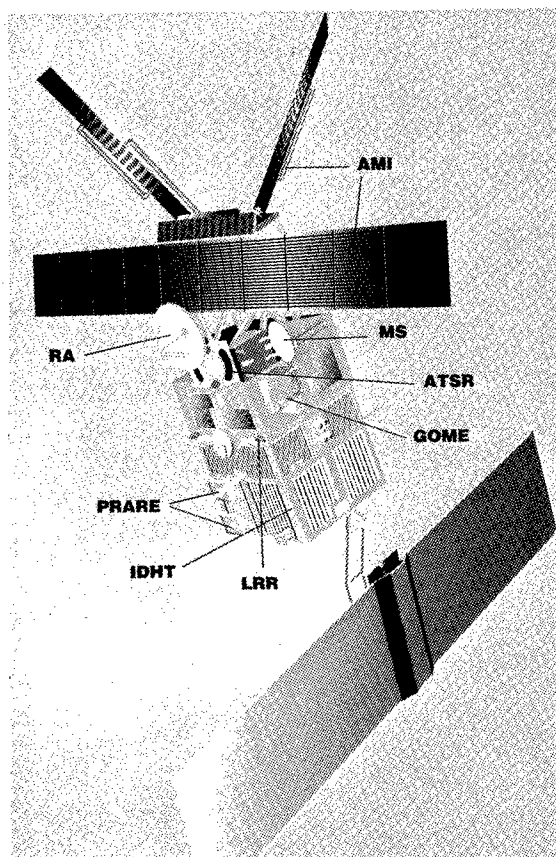


FIGURE 4.64 ERS-2 SATELLITE.

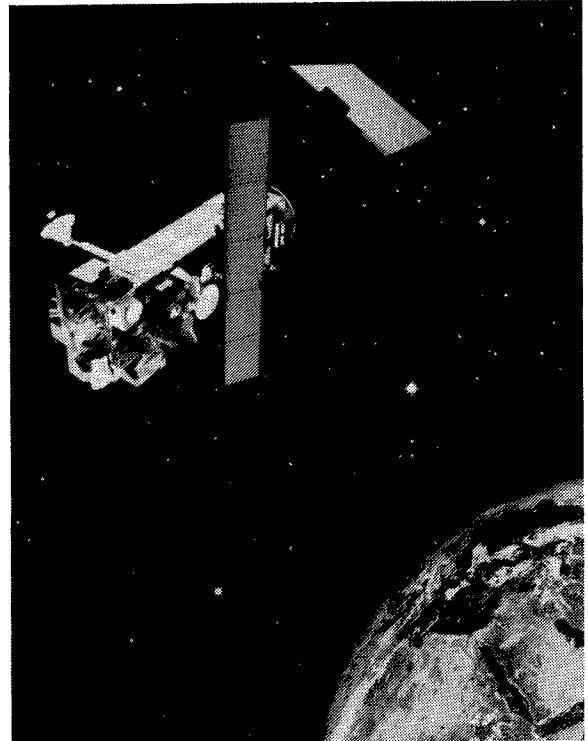


FIGURE 4.65 ENVISAT POLAR PLATFORM.

spacecraft encountered new obstacles in late 1994 when the US considered integrating the civilian NOAA and military DMSP programs. European officials were concerned about US Department of Defense control over Metop-1 and hoped to resolve the difficulties during 1995 (References 499, 527-532).

#### 4.3.2 France

Since 1986 France has operated the highly regarded SPOT (Satellite Pour l'Observation de la Terre) high resolution imaging satellite system. Developed and funded by CNES, SPOT is managed on a commercial basis by SPOT Image with multi-national shareholders, which hope to be free of all government subsidies by the late 1990's (Reference 533). Experience gained by the French through the SPOT program is being applied to a series of space endeavors including ESA's Polar Platform and French national security satellites.

SPOT satellites orbit the Earth at an altitude near 825 km and an inclination of  $98.7^\circ$  to produce a 26-day repeating groundtrack pattern with sun-synchronous conditions. SPOT 3 joined SPOT 1 (February, 1986) and SPOT 2 (January, 1990) after its launch on 26 September 1993. All three spacecraft are in essentially co-planar orbits.

Each successive SPOT spacecraft has been approximately 40 kg heavier than its predecessor, culminating in SPOT 3's 1,907 kg launch mass. The spacecraft bus is 2 m by 2 m by 3.5 m with a hydrazine-controlled 3-axis stabilization system (Figure 4.66). A 15.6-m-long solar array produces nearly 1.4 kW of electrical power at start of life.

The heart of SPOT is a pair of high resolution visible CCD scanners with both multi-spectral (0.50-0.59  $\mu\text{m}$ , 0.61-0.68  $\mu\text{m}$ , and 0.79-0.89  $\mu\text{m}$ ) and panchromatic (0.51-0.73  $\mu\text{m}$ ) features. The former mode returns images with a ground resolution of 20 m, while the latter is capable of 10 m resolution. The swath of each scanner is 60 km, but the pair can be operated simultaneously to produce a 117 km swath with a small (3 km) overlap region. Off-nadir viewing is also possible with the aid of a tilting mirror extending the swath to 80 km for each scanner at an angle of 27° from nadir. Images can be transmitted in realtime directly to a world-wide network of ground stations or may be stored on board the spacecraft for later downlinking via two Odetics tape recorders, which were improved for SPOT 3. SPOT 3 also carried the US Polar Ozone and Aerosol Measurement (POAM) experiment (References 534-539).

Developed by a team led by Matra Marconi and Aerospatiale, SPOT 1 was initially retired at the end of 1990, nearly two years past its design life of three years. However, the spacecraft was recalled to service during March-October, 1992, and April-July, 1993, to help meet imaging demands during the principal Northern Hemisphere growing season, although both its tape recorders had failed. The vehicle was placed in standby mode again after SPOT 3 was declared operational. SPOT 2, also with limited tape recording capability, serves as the prime backup to SPOT 3 as new uses of the SPOT system continue to be found (References 540-547).

Whereas the 2,500 kg SPOT 4, scheduled for launch in 1997, will possess several significant improvements over its predecessors (in particular, greater power availability, longer life, and additional mid-IR band of 1.58-1.75  $\mu\text{m}$ ), SPOT 5 (~2000) and SPOT 6 (~2005) will represent the second generation SPOT spacecraft. The imaging instruments will be modified to permit 5-m resolution or better in each of two bands (panchromatic and near-IR) while the multi-spectral capability will be improved to 10-

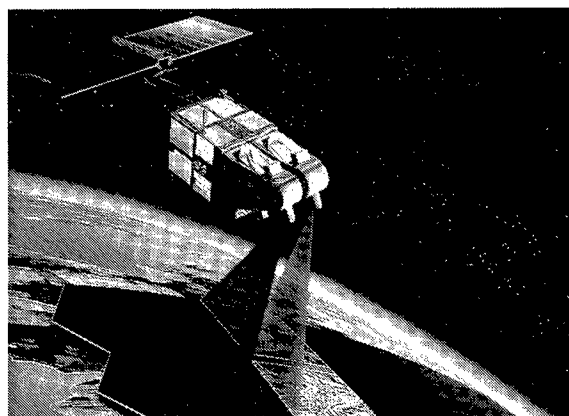


FIGURE 4.66 SPOT SATELLITE.

m resolution. The mass of the spacecraft will likely be at least 1,000 kg more than SPOT 4. Greater use of stereo imaging will also be possible (References 527, 548-555).

Studies are also underway for a SPOT variant hosting a synthetic aperture radar not unlike ERS (Reference 556). Another French proposal named BEST would carry even more sophisticated radar and lidar sensors for environmental studies (Reference 557). Meanwhile, French Earth observations are operational on the multinational Topex/Poseidon (DORIS [Doppler Orbitography and Radio-positioning Integrated Satellite] and radar altimeter) and UARS (Wind Imaging Interferometer). In 1994 the French SCARAB radiometer was flown on a Russian Meteor 3 spacecraft, in 1995 the French Alissa lidar will be on board the Russian Priroda module for the Mir space station, and in 1996 the French POLDER instrument will be carried by the Japanese ADEOS spacecraft (Section 4.3.7).

#### 4.3.3 Germany

Earth observation pursuits by Germany have to date been restricted to the development of domestic remote sensing instruments for flight opportunities on foreign spacecraft, most notably those of ESA and the US. During 1989-1991 studies were undertaken for the design of a dedicated German satellite, Atmos, which would have concentrated investigations on the Earth's atmosphere. From a 775-km, sun-synchronous orbit, Atmos was to have been launched in the mid-1990's with four major Earth observation systems: the Advanced Millimeter Wave Atmospheric Sounder (AMAS), the Michelson Interferometer for Passive Sounding (MIPAS), the Scanning Imaging Absorption

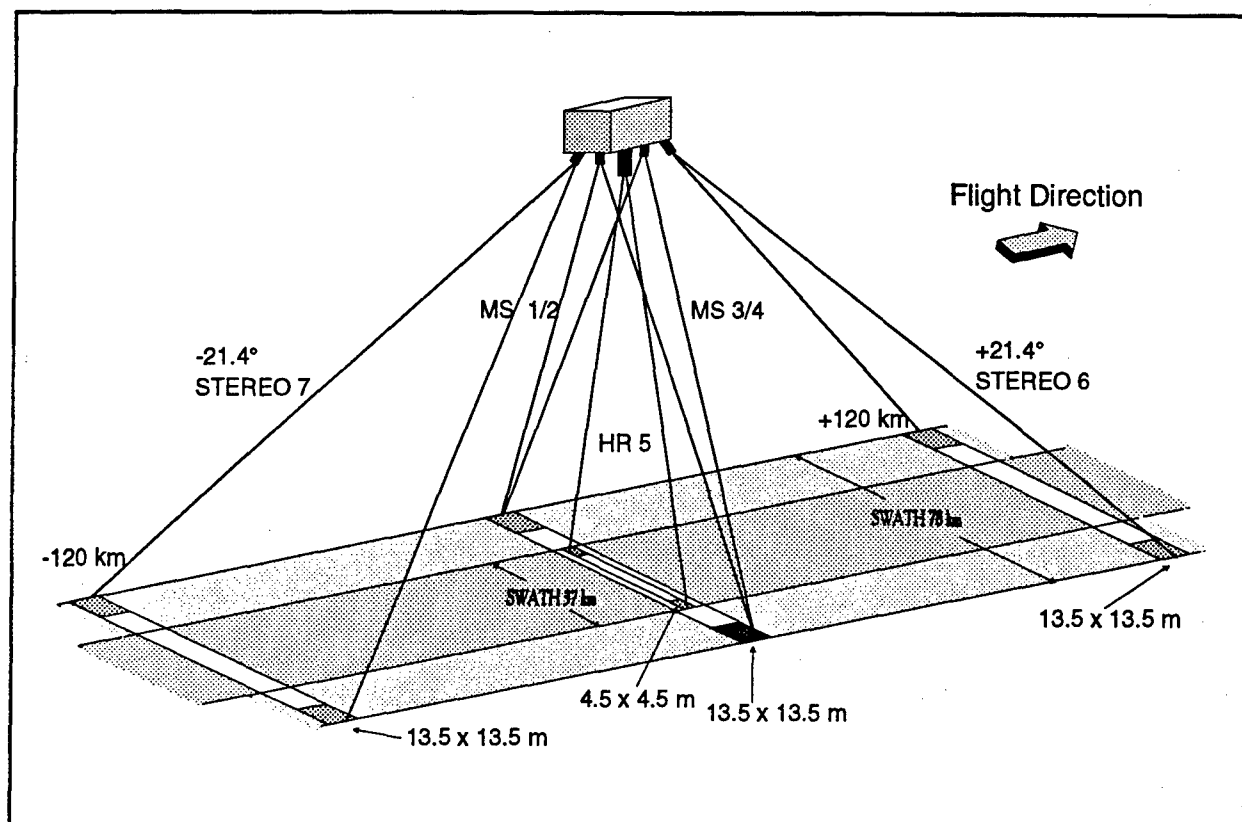


FIGURE 4.67 MOMS-02 IMAGING GEOMETRY.

Spectrometer for Atmospheric Cartography (SCIAMACHY), and the Reflective Optics Imaging Spectrometer (ROSIS). The first three devices were designed to analyze atmospheric chemistry, whereas the objective of ROSIS was to return moderate and high resolution, multi-spectral photographs of the Earth's surface (Reference 558). The Atmos program has been reoriented to provide some or all of the above mentioned instruments to ESA's Envisat satellite (Section 4.3.1).

In addition to its contributions to the ESA ERS (led by Germany with a 24% contribution) and the ESA/EUMETSAT Meteosat programs, German interest in Earth observation studies is reflected in the X-SAR payload to be flown on several US Shuttle missions and, to a lesser extent, the STS-Spacelab D2 mission of April-May, 1993. The X-SAR (X-band Synthetic Aperture Radar) was developed jointly by Germany (Dornier) and Italy (Alenia), uses a 3.3 kW peak power beam to scan a swath of 15-45 km with resolutions as low as 10 m, and was first flown on STS-59 in April, 1994 with a reflight on STS-68 in September, 1994 (Reference 559).

Spacelab D2 (STS-55) carried Germany's Modular Optoelectronic Multispectral Stereo Scanner (MOMS-02), an advancement of the MOMS-01 flown on STS-7 and STS-11. MOMS-02 is a 7-channel, high resolution imaging system with four multispectral channels (0.449-0.511, 0.532-0.576, 0.645-0.677, and 0.772-0.815  $\mu\text{m}$ ) with 13.5 m resolution (Figure 4.67). The 1993 mission was highly successful, producing over 1,300 scenes. MOMS-02 will next be flown on the Russian Priroda module to be attached to the Mir space station as early as 1995 (References 560-563).

In 1993 Germany had hoped also to orbit the second Monocular Electro-Optical Stereo Scanner (MEOSS) on board India's IRS-1E spacecraft. Unfortunately, the spacecraft was lost in a PSLV launch failure. The original MEOSS was lost on SROSS 2 when its ASLV booster malfunctioned.

#### 4.3.4 India

Earth observations have played a prominent role in the majority of Indian satellites launched to date. Two of the three space



launches attempted by India during 1993-1994 carried Earth observation spacecraft under the Indian Remote Sensing Satellite (IRS) program: IRS-1E in 1993 and IRS-P2 in 1994. This followed the launch of three Indian remote sensing spacecraft (by India, the USSR, and ESA) during the previous 2-year period. The scientific secretary of the Indian Space Research Organization, M.G. Chandrasekhar, is also the Director for Earth Observation programs.

Following the successful demonstration flights of Bhaskara 1 and Bhaskara 2 launched in 1979 and 1981, respectively, India began development of an indigenous IRS program to support the national economy in the areas of "agriculture, water resources, forestry and ecology, geology, water sheds, marine fisheries and coastal management" (Reference 564). The first two IRS spacecraft, IRS-1A (March, 1988) and IRS-1B (August, 1991) were launched by Russian Vostok boosters from the Baikonur Cosmodrome. Both vehicles continued to operate well through the end of 1994.

From their 22-day repeating orbits of 905 km mean altitude and 99° inclination, the two identical IRS spacecraft host a trio of Linear

Imaging Self-Scanning (LISS) remote sensing CCD instruments working in four spectral bands: 0.45-0.52  $\mu\text{m}$ , 0.52-0.59  $\mu\text{m}$ , 0.62-0.68  $\mu\text{m}$ , and 0.77-0.86  $\mu\text{m}$ . The 38.5-kg LISS-I images a swath of 148 km with a resolution of 72.5 m while the 80.5-kg LISS-IIA and LISS-IIB exhibit a narrower field-of-view (74-km swath) but are aligned to provide a composite 145-km swath with a 3-km overlap and a resolution of 36.25 m.

Each IRS spacecraft is 975 kg at launch with a design life of 2.5-3 years. The 3-axis stabilized spacecraft is essentially rectangular (1.1 m by 1.5 m by 1.6 m) with two narrow solar arrays producing less than 1 kW electrical power (Figure 4.68). The Spacecraft Control Center at Bangalore oversees all spacecraft operations, but the principal data reception station for the remote sensing payload is located at Shadnagar. Spacecraft data transmissions are effected via X-band and S-band antennas at the base of spacecraft.

IRS-1A and IRS-1B were to be joined in 1993 with IRS-1E, the modified IRS-1A engineering model, which had been equipped with the LISS-I and a German Monocular Electro-

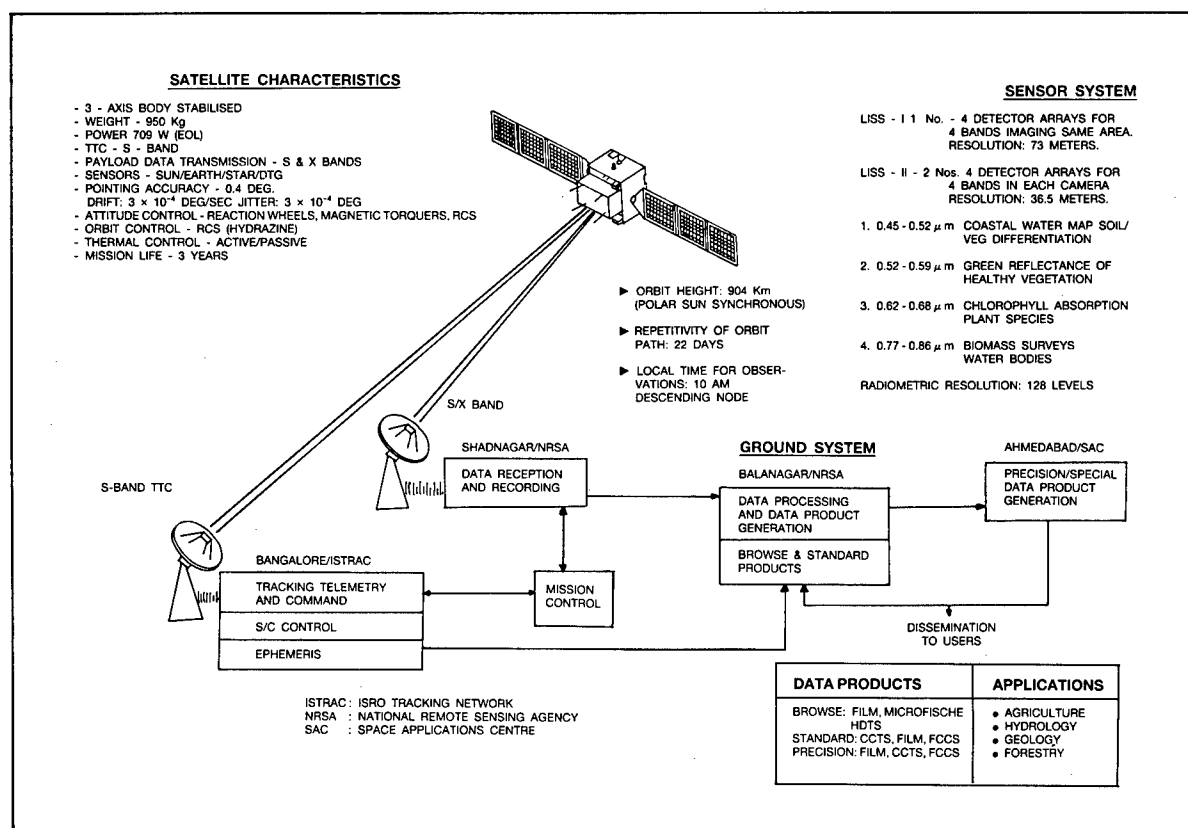


FIGURE 4.68 IRS EARTH OBSERVATION SYSTEM.

Optical Stereo Scanner. The spacecraft was lost, however, when its PSLV launch vehicle failed to reach Earth orbit (Section 2.3). Thirteen months later, in October, 1994, the PSLV functioned correctly, allowing IRS-P2 to assume an 820-km, sun-synchronous orbit. With an 870-kg mass (slightly less than IRS-1A and IRS-1B), IRS-P2 carried the LISS-II system with a ground resolution of 32 m across-track and 37 m along-track. The total swath width is 131 km, and the CCD array is tuned to four spectral bands between 0.45 and 0.86  $\mu\text{m}$ . The spacecraft's solar arrays provide up to 500 W and are linked to conventional nickel cadmium storage batteries (References 565-570).

India's ambitious IRS program envisions three more spacecraft (IRS-P3, IRS-1C, and IRS-1D) in orbit by the end of 1996. IRS-P3 is to be launched by PSLV in 1995 with a German modular electro-optical scanner and an Indian visible-IR scanner. IRS-1C and IRS-1D will introduce a heavier (1,350 kg), more capable Earth observation platform. The spacecraft bus will be similar to those of IRS-1A and IRS-1B, but a slightly larger solar array will generate more than 800 W. The payload suite will include the 4-band (0.52-0.59, 0.62-0.68, 0.77-0.86, and 1.55-1.70  $\mu\text{m}$ ) LISS-III (resolution down to 22 m), and 8-m resolution panchromatic (0.5-0.75  $\mu\text{m}$ ) imager, and a 2-channel (0.62-0.68 and 0.77-0.86  $\mu\text{m}$ ) wide-field sensor (190 m resolution). IRS-1C will be the last Russian launch of the program (Molniya rather than Vostok), while IRS-1D will be orbited by India's PSLV (References 568-569, 571-575).

As noted in the section on communications satellites, India's INSAT series of geostationary spacecraft perform the dual missions of communications and meteorology. INSAT 1-class satellites carry a Very High Resolution Radiometer (VHRR) working in the visible (0.55-0.75  $\mu\text{m}$ ) and IR (10.5-12.5  $\mu\text{m}$ ) bands with resolutions of 2.75 km and 11 km, respectively. Like many GEO meteorological satellites, INSAT 1 spacecraft require 30 minutes to complete a full Earth scan. Each vehicle is also capable of receiving (on 402.75 MHz) meteorological, hydrological, and oceanographic data from remote data collection platforms for relay to central Indian processing centers.

The INSAT 2 program was inaugurated in 1992 with the launch of INSAT 2A, followed by INSAT 2B in 1993. The spacecraft characteris-

tics and communications payload are described in Section 4.1.7. For Earth observations, the VHRR was improved with 2-km resolution in the visible band and 8-km resolution in the IR band. In addition to full Earth images, the VHRR can be commanded to scan very limited regions for more rapid return of time-critical data, e.g., during the approach of cyclones to the sub-continent. INSAT 2 satellites also carry the Data Relay Transponder system for collection and retransmission of data from DCPs. Three additional INSAT 2 satellites are expected to maintain this GEO Earth observation capability into the next century.

#### 4.3.5 Israel

By the end of 1994, Israel's fledgling space program had produced only two, short duration, LEO satellites of a primarily engineering nature. The 1994 launch of a 55-kg, 45-cm cube micro-satellite named Techsat (aka Gurwin) was postponed until 1995. Originally planned for launch into a sun-synchronous orbit as a piggy-back payload during an Ariane mission, Techsat was later manifested for the inaugural launch of the 5-stage Russian Start booster. Designed and built by the Israel Space Agency, Haifa's Technion Institute, and others, Techsat was outfitted with a simple CCD television system for Earth observation purposes. The planned orbit for Techsat is approximately 670 km in a prograde, near-polar inclination.

#### 4.3.6 Italy

Although Italy's series of small San Marco satellites (1964-1988) included some upper atmospheric studies, Earth observation was not a principal objective. In 1987 development began on the German-Italian X-SAR project to produce an X-band synthetic aperture radar for flight on the US Space Shuttle. The first two missions were flown on STS-59 (April, 1994) and STS-68 (September, 1994). X-SAR's 10-m long, 0.4 m wide antenna operated at a frequency of 9.6 GHz with a resolution as small as 10m. An advanced X-SAR design is currently under investigation (References 558-559, 576-577).

On 31 August 1993, Italy's Temisat micro-satellite was launched along with the Russian Meteor 2-21 spacecraft. Although essentially a small data relay satellite, one of Temisat's primary missions is to collect environmental data

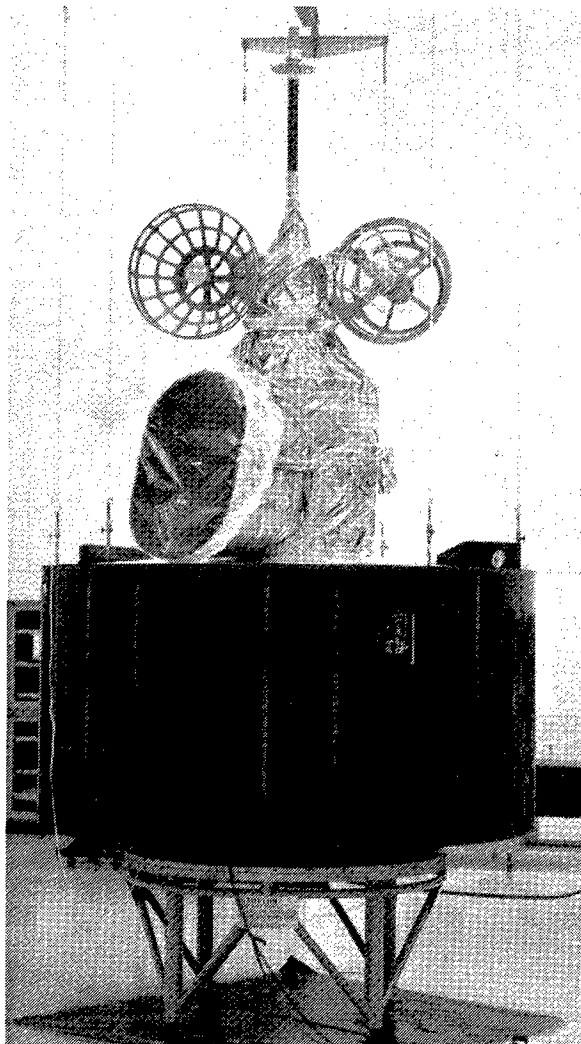


FIGURE 4.69 GMS SATELLITE.

from as many as 1,000 ground sensors and retransmit the information to central data processing facilities.

Alenia Spazio, the primary Italian firm which supported X-SAR, is now promoting the Constellation for Mediterranean Observation (COSMO) concept of seven small (550 kg) satellites for Earth observation. Four of the spacecraft would be equipped with a synthetic aperture radar, while the other three vehicles would carry optical sensors. As envisioned, COSMO would be sponsored by Italy, Greece, and Spain but would make its products available to the general European community. COSMO follows the earlier Alenia Spazio designer for a heavier, multi-frequency platform (References 578-580).

#### 4.3.7 Japan

Japan recently has operated three types of Earth observation systems: one for meteorol-

ogy, one for oceanography, and one for general remote sensing. Although no new missions in any of these programs were conducted in 1993-1994, two of the networks remained active, while the third was degraded by the end of 1994. Japan is poised to enter a new era of advanced Earth observations now that the H-II launch vehicle is operational. At least four new types of spacecraft are scheduled for launch by the turn of the century.

Japan's Geostationary Meteorological Satellite (GMS) system was originally developed by NASDA relying heavily on the US GOES design and is now jointly run by NASDA and the Japan Meteorological Agency. The American firm of Hughes is the prime contractor, working for Japan's NEC Corporation. Four GMS spacecraft have been launched since 1977, the last in September, 1989. GMS-3 (August, 1984) is available for backup operations at  $120^{\circ}$  E, while GMS-4 is located in the primary position at  $140^{\circ}$  E. As with all national satellites, GMS spacecraft are also known by a specific Japanese name, in this case, Himawari, meaning "sunflower." GMS-5, the final satellite in the series, is scheduled for launch by the H-II booster in 1995.

GMS-4 is a spin-stabilized (100 rpm) spacecraft with an on-orbit mass of approximately 325 kg, a diameter of 2.1 m and a height (after apogee kick motor separation) of 3.4 m (Figure 4.69). Solar cells applied to the exterior of the

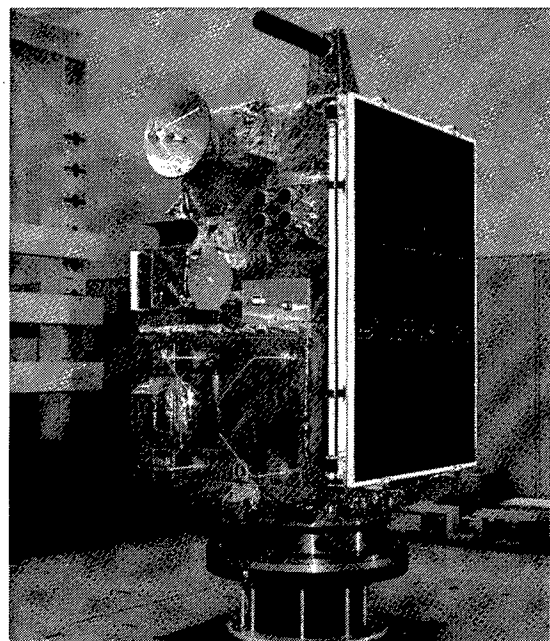


FIGURE 4.70 MOS 1 SATELLITE.

spacecraft bus generate up to 300 W, and the overall design life is five years. Hydrazine thrusters maintain the desired geostationary position and counteract perturbations attempting to alter the vehicle's inclination.

The major Earth-oriented instrument is the Visible and Infrared Spin Scan Radiometer (VISSR), "used to obtain visible and infrared spectrum mappings of the Earth and its cloud cover with a specially designed optical telescope and detector system" (Reference 581). Visible images are collected in the 0.50-0.75  $\mu\text{m}$  band with a resolution of 1.25 km, and the infrared signatures are taken in the 10.5-12.5  $\mu\text{m}$  band with a 5.0-km resolution. Thirty minutes are required to obtain a full Earth image consisting of 2,500 narrow strips. A separate payload, called the Space Environment Monitor (SEM), measures the flux of solar protons, alpha particles, and electrons.

While outwardly almost identical to GMS-4, GMS-5 will host a more sophisticated VISSR with one visible band (0.55-0.9  $\mu\text{m}$ ) and three IR bands (10.5-11.5  $\mu\text{m}$ , 11.5-12.5  $\mu\text{m}$ , and 6.5-7.0  $\mu\text{m}$ ). The relative visible and IR resolution will remain unchanged. The height of the spacecraft will increase slightly to 3.5 m as will the on-orbit mass of 338 kg. In place of the SEM, an experimental COSPAS-SARSAT transponder will be carried (Reference 582). A successor to the GMS series is expected by 1999 under the MTSAT (Multi-functional Transport Satellite) program. Specifications and a contract award are expected to be released in 1995.

Space-based oceanography is conducted in Japan by two Marine Observation Satellites (MOS) placed in sun-synchronous orbits of approximately 910 km with an inclination of 99.1°. After 10 years of development MOS 1 (aka Momo 1 or "peach tree") was launched in February, 1987, and was followed by MOS 1b (Momo 1b) in February, 1990, into an orbital plane only a few degrees away from MOS 1. The program objectives include:

- Development of observation sensors; verification of their functions and performances, and experimental observation of the Earth (in particular the oceans) using such sensors;
- Basic experiments on a data collection system (DCS);
- Establishment of fundamental technologies for Earth observation satellites" (Reference 583).

Funded and managed by NASDA, the MOS program selected NEC Corporation as the prime contractor with significant assistance by Mitsubishi Electric, Toshiba, and Fujitsu. Each 740-kg, 3-axis-stabilized spacecraft (Figure 4.70) consists of a box-shape bus (1.3 m by 1.5 m by 2.4 m) with a single solar array (2.0 m by 4.5 m). The selected orbit permits a repeating groundtrack with a period of 17 days.

The MOS payload consists of four primary classes of instruments. Two 70-kg Multi-spectral Electronic Self-Scanning Radiometers (MESSR) return images in four bands (0.51-0.59  $\mu\text{m}$ , 0.61-0.69  $\mu\text{m}$ , 0.72-0.80  $\mu\text{m}$ , and 0.80-1.1  $\mu\text{m}$ ) with a ground resolution of 50 m and a swath of 100 km. The fields-of-view of the two MESSR sensors are slightly overlapped (15 km) to provide stereo viewing. The 25-kg Visible and Thermal Infrared Radiometer (VTIR) operates in one visible and three IR bands: 0.5-0.7  $\mu\text{m}$ , 6-7  $\mu\text{m}$ , 10.5-11.5  $\mu\text{m}$ , and 11.5-12.5  $\mu\text{m}$  with ground resolutions of 900 m (visible) and 2,700 m (IR) and a swath of 1,500 km. The 54-kg Microwave Scanning Radiometer (MSR) is tuned to two frequencies: 23.8 GHz and 31.4 GHz. The swath is 317 km with respective resolutions of 23 km and 32 km. Finally, the Data Collection System Transponder (DCST) collects data from DCP's transmitting in the 400 MHz band and relays the information to data acquisition and processing facilities at a frequency of 1.7 GHz. MESSR and VTIR data are transmitted at 1.7 GHz and 8 GHz, while MSR data are downlinked at 2 GHz. MOS 1 and MOS 1b are expected to remain operational until

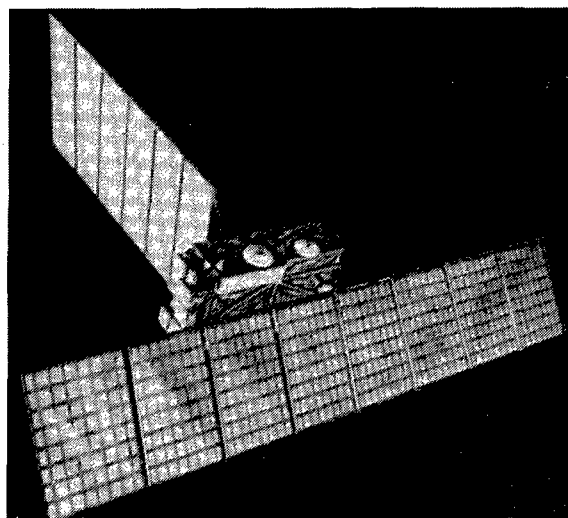


FIGURE 4.71 JERS-1 SATELLITE.

about 1997 and 2001-2002, respectively (References 583-585).

The Japan Earth Resources Satellite (JERS-1 aka Fuyo 1) was launched in February, 1992, into a 570-km, sun-synchronous orbit. The 12-year effort to field the moderate resolution SAR and multi-spectral payload was a joint venture by NASDA, which was responsible for the spacecraft, by the Ministry of International Trade and Industry, which developed the payload instruments, and by the Science and Technology Agency. Mitsubishi Electric was the prime contractor aided by Toshiba, Nippon Electric, and the Japanese Resources Observation Systems Organization.

The 1,340 kg JERS-1 (Figure 4.71) consists of a flat rectangular bus (0.9 m by 1.8 m by 3.2 m) with a single 2-kW solar array (3.5 m by 7.0 m) and an eight-segmented SAR antenna (2.4 m by 11.9 m when deployed). The spacecraft is 3-axis stabilized with a payload of nearly 500 kg and a design life of two years. Frequent orbital adjustments are required to maintain the 44-day repeating groundtrack.

The spacecraft carries two closely matched Earth observation sensors: the SAR and the OPS multi-spectral imager. The SAR operates at a frequency of 1.275 GHz with a peak power of 1.3 kW, a 75-km swath, and an 18-m resolution. The SAR mission was placed in jeopardy for two months when the large radar antenna failed to deploy fully. On 4 April 1992 the spacecraft signaled that the first stage of deployment was finally accomplished, and by 9 April the full antenna array was in position. Images returned by the SAR in late April lived up to expectations, although some minor interference problems appeared later in the year (References 586-592).

The OPS system is comprised of a 3-band, CCD Visible and Near-IR Radiometer (VNIR) using 0.52-0.60  $\mu\text{m}$ , 0.63-0.69  $\mu\text{m}$ , and 0.76-0.86  $\mu\text{m}$  regimes and a 4-band, CCD Short Wavelength IR Radiometer (SWIR) sensitive to 1.60-1.71  $\mu\text{m}$ , 2.01-2.12  $\mu\text{m}$ , 2.13-2.25  $\mu\text{m}$ , and 2.27-2.40  $\mu\text{m}$ . The resolution of the OPS is matched to that of the SAR at 18 m. A mission data recorder is available to store images until downlinked by the mission data transmitter at 8.15 GHz and 8.35 GHz. JERS-1 continued to experience sensor difficulties, and in late 1993 the SWIR failed due to a cooling problem. The remainder of the spacecraft's instruments were

still operational at the end of 1994 (References 593-595).

Japan's next major remote sensing satellite undertaking is the Advanced Earth Observing Satellite (ADEOS), slated for launch in 1996 by the H-II booster. The objectives of the program are "to acquire data on worldwide environmental changes such as the greenhouse effect, ozone layer depletion, tropical rain forest deforestation, and abnormal climatic conditions, in order to contribute to international global environmental monitoring and to develop platform bus technology, interorbital data relay technology, etc. which are necessary for the development of future Earth observation systems" (Reference 596).

The 3.5-metric-ton ADEOS will operate in an 800-km orbit with an inclination of 98.6°. Developed jointly by Mitsubishi Electric, Toshiba, and Nippon Electric, the ADEOS configuration employs an irregularly shaped bus (3.5 m by 3.5 m by 4 m) with a single solar array (3 m by 13 m) capable of generating a minimum of 4.5 kW during the anticipated 3-year lifetime of the satellite (Figure 4.72). Hydrazine thrusters will maintain a precise 41-day repeating groundtrack.

An extensive, complex payload consisting of Japanese, American, and French remote sensing instruments is planned for ADEOS. NASDA will directly contribute an Advanced Visible and Near-IR Radiometer (5 bands, 8-m and 16-m resolution, 80-km swath) and the Ocean Color and Temperature Scanner

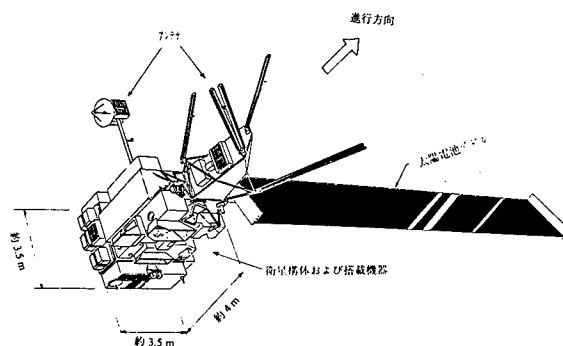


FIGURE 4.72 ADEOS SATELLITE.

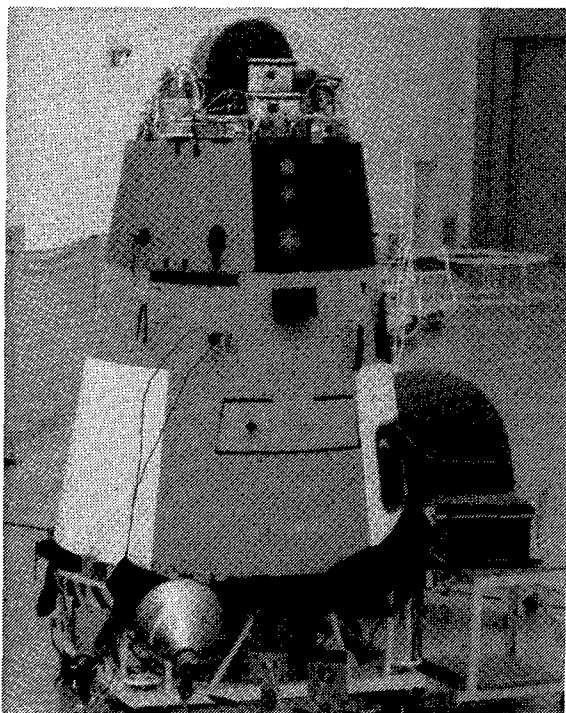


FIGURE 4.73 FSW SATELLITE.

(12 bands, 700-m resolution, 1,400-km swath). The Japanese Environment Agency will provide the Improved Limb Atmospheric Spectrometer and the Retroreflector in Space, while the Ministry of International Trade and Industry supplies the Interferometric Monitor for Greenhouse Gases. The three foreign instruments to be hosted by ADEOS are the Total Ozone Mapping Spectrometer (NASA), the Scatterometer (NASA), and the French POLDER (Polarization and Directionality of the Earth's Reflectance). A follow-on ADEOS mission is tentatively scheduled for 1999 (References 596-600).

Japan is also a principal participant in the international Tropical Rainfall Measuring Mission (TRMM) scheduled to begin in 1997. Japan will launch the 3.5-metric-ton satellite built by NASA into a 350-km orbit with a low inclination of 35°. Accompanying four NASA instruments will be the Japanese Precipitation Radar, operating at 13.8 GHz and sponsored by NASDA with Toshiba as the prime contractor. For the longer term, Japan envisions establishing a Global Earth Observation System comprised of a variety of low and high altitude satellites. One of the new spacecraft joining this fleet is the proposed Advanced Land Observing Satellite (ALOS), which may be placed into a 700-km, sun-synchronous orbit by the year 2000 with a synthetic aperture radar and a version of the

visible and near-IR radiometer design for ADEOS (References 585, 597, 601-603).

#### 4.3.8 Pakistan

Although Pakistan has only operated one small satellite in LEO (Badr-A, 16 July-20 August 1990, orbited as a secondary payload by a Chinese booster), the country's modest space program has long been oriented toward remote sensing applications. A data processing infrastructure has been established to exploit Earth observation data transmitted by Landsat, NOAA, and SPOT satellites. As a next step, the Space and Upper Atmosphere Research Commission (SUPARCO) is preparing for the commercial launch of a simple Pakistani satellite with Earth imaging capabilities.

The 50-kg Badr-B now in final development will be a cube with side dimensions of 45 cm and a gravity-gradient stabilization system. The project plan envisions a 2-3 year mission for a CCD camera in an 800-km, sun-synchronous orbit. A plan to launch Badr-B in 1994 did not materialize, and it was hoped that a ride could be found in 1995 or 1996 (References 604-608).

#### 4.3.9 People's Republic of China

The PRC has been actively pursuing Earth observation space systems for more than twenty years and in 1975 became only the third country in the world to retrieve high resolution photographs of the planet shot from space. Today, two models of LEO recoverable Earth

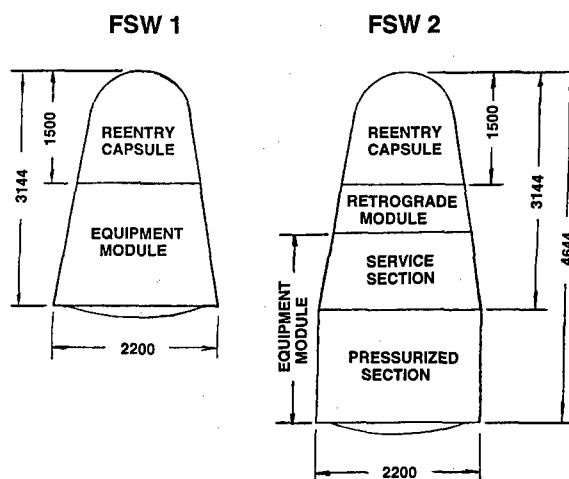


FIGURE 4.74 FSW-1 AND FSW-2 SATELLITES.

observation satellites are in use and a sun-synchronous meteorological satellite system has been tested. PRC's first GEO meteorological satellite was lost in a ground accident in early 1994, but plans for the launch of a replacement in 1995-1996 are underway.

Designed to support both military and civilian Earth observation needs, the FSW (Fanhui Shi Weixing, i.e., Return Test Satellite) program began in 1966 with an initial launch failure in 1974. Recent Chinese descriptions of the program have shed new light on the FSW series which by the end of 1994 had flown 16 spacecraft in LEO. The original FSW-O variant completed nine orbital missions during 1975-1987 after the maiden launch failure of November, 1974. The FSW-1 model was introduced in September, 1987 (five flights to date), followed by the FSW-2 in August, 1992 (two flights to date). During 1993-1994 a single mission for each of the FSW-1 and FSW-2 was conducted.

Launched by the CZ-2C booster from Jiuquan, the FSW-1 (Figure 4.73) has a blunt conical shape with a length of 3.14 m, and a maximum diameter of 2.2 m, and a mass of up to 2.1 metric tons. The vehicle is divided into two major sections: the equipment and retro module (1.6 m long) and the reentry module (1.5 m long). The 3-axis-stabilized FSW-1 is powered by batteries and is controlled from the Xian Satellite Control Center. The nominal flight duration is 7-10 days (References 609-611).

FSW-1 satellites have carried imaging payloads with high resolution (10-15 m) cameras for film development on Earth and with CCD (50-m resolution) camera systems for near-real-time images. The latter system can also be used in directing the operation of the former system, thereby minimizing the wastage of film supplies if environmental conditions are unfavorable, e.g., cloud-covered. The maximum recoverable payload is 180 kg, while the maximum non-recoverable payload is 250 kg (References 611-614).

The only FSW-1 mission conducted during 1993-1994 was launched on 8 October 1993 into an orbit of 209 km by 300 km at an inclination of 57.0°. In addition to an Earth observation payload, FSW-1 5 carried microgravity research equipment and a diamond-studded medallion commemorating the 100th anniversary of Chairman Mao Tse-Tung's birth. The spacecraft operated normally until 16 October when an attempt to recover the satellite failed. An atti-

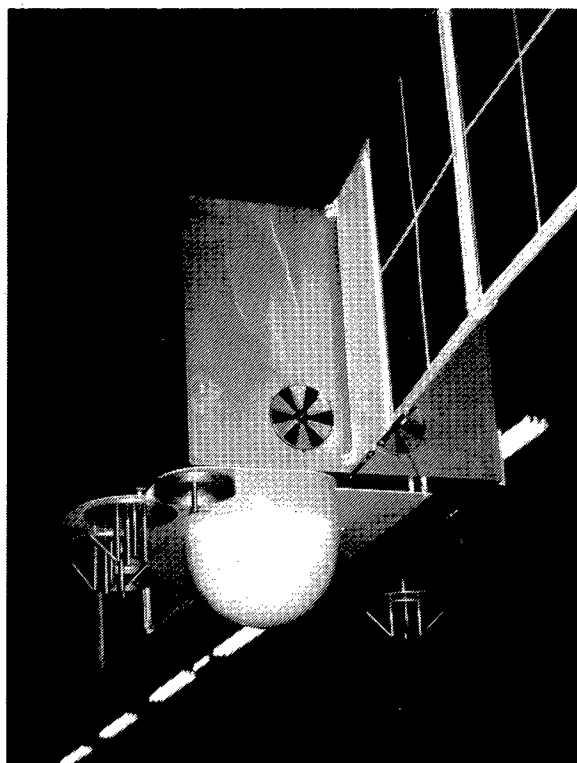


FIGURE 4.75 FENG YUN-1 SATELLITE.

tude control system failure aligned the spacecraft 90° from its desired position, causing the reentry capsule to be pushed into a higher elliptical orbit (179 km by 3031 km) instead of returning to Earth. Natural decay will not bring the capsule back until late 1995 or 1996 (References 615-620).

The FSW-2 debuted on 9 August 1992 with a launch by the new CZ-2D booster from Jiuquan. The heavier (2.4-3.1 metric ton) FSW-2 resembles the FSW-1 with an additional cylindrical module 2.2 m in diameter and 1.5 m long for a total length of 4.6 m (Figure 4.74). The major advantages of the newer model are an increased payload (350 kg maximum recoverable; 400 kg maximum non-recoverable) and a longer mission duration (up to 18 days). Unlike the FSW-1, the FSW-2 has a modest mono-propellant orbital maneuver capability (References 609-611, 621).

The second FSW-2 was launched on 3 July 1994 into an orbit of 173 km by 343 km at an inclination of 63.0°. The spacecraft remained in orbit for 15 days, making four small maneuvers before successfully returning to Earth. The payload included Earth observation systems, a biological experiment, and microgravity research instruments.

A general reference was made in a 1989 scientific paper about the development of a second generation of recoverable satellites which would be "much larger, heavier, and more advanced than FSW-2" (Reference 609). The new spacecraft would also incorporate more sophisticated reentry lift techniques to improve landing precision and to lessen deceleration forces, which are currently as high as 20 g's for FSW capsules. No subsequent discussion of this proposed satellite has ensued.

In 1988 and again in 1990 the PRC launched Feng Yun 1 meteorological satellites into approximately 900-km, 99° inclination orbits by CZ-4 boosters from Taiyuan. The spacecraft were designed to be comparable to existing international LEO meteorological and remote sensing systems, including APT transmissions in the 137 MHz band. The satellite structure and support systems were created by the Shanghai Satellite Engineering and Research Center of the China Space Technology Institute, whereas the payload was developed by the Shanghai Technical Physics Institute of the Chinese Academy of Sciences.

Both satellites were experimental to test systems prior to the launch of operational Feng Yun 1 spacecraft and were similar in design, although technical characteristics differed. The height of the cubical spacecraft bus (1.4 m by 1.4 m base) of Feng Yun 1A was apparently increased from 1.2 m to nearly 1.8 m for Feng Yun 1B (Figure 4.75). Likewise, total spacecraft mass increased from 750 kg to about 880 kg. Both satellites were powered by two solar arrays (about 3.5 m long each) with a combined rating of more than 800 W. Nickel-cadmium batteries were used for electrical power storage. Attitude control was maintained by a combination of nitrogen cold gas thrusters and reaction wheels, although both spacecraft suffered serious malfunctions in this system. Feng Yun 1A was lost after only 38 days, but Feng Yun 1B operated for more than a year (References 622-624).

The Feng Yun 1 primary payload consisted of two Very High Resolution Scanning Radiometers (VHRSR) with a combined mass of 95 kg. These optical-mechanical scanners operated at 360 rpm with a 20-cm diameter primary mirror. The five spectral bands used were 0.58-0.68  $\mu\text{m}$ , 0.725-1.1  $\mu\text{m}$ , 0.48-0.53  $\mu\text{m}$ , 0.53-0.58  $\mu\text{m}$ , and 10.5-12.5  $\mu\text{m}$ . The system swath was 2,860 km with a 1.08-km resolution in the High Reso-

lution Picture Transmission (HRPT) mode and 4-km resolution in the Automatic Picture Transmission (APT) mode.

Two improved Feng Yun 1 spacecraft are expected to be launched toward the end of this decade. Feng Yun 1C and 1D will probably carry a 10-channel scanning radiometer with a resolution equal to that of Feng Yun 1A and 1B. A second-generation LEO observation satellite called Feng Yun 3 is reportedly under development with substantially advanced multispectral imaging systems (Reference 625).

In 1994 the long-awaited Feng Yun 2 GEO meteorological spacecraft was to be launched and positioned at 105° E. The spacecraft will be slightly more massive than PRC's DFH-2 communications satellite and will be spin-stabilized like its foreign counterparts. The Feng Yun 2 spacecraft bus diameter will be 2.1 m, and the total height on-station will be about 4.5 m. The two principal sensors will be visible and IR imaging instruments with best resolutions of

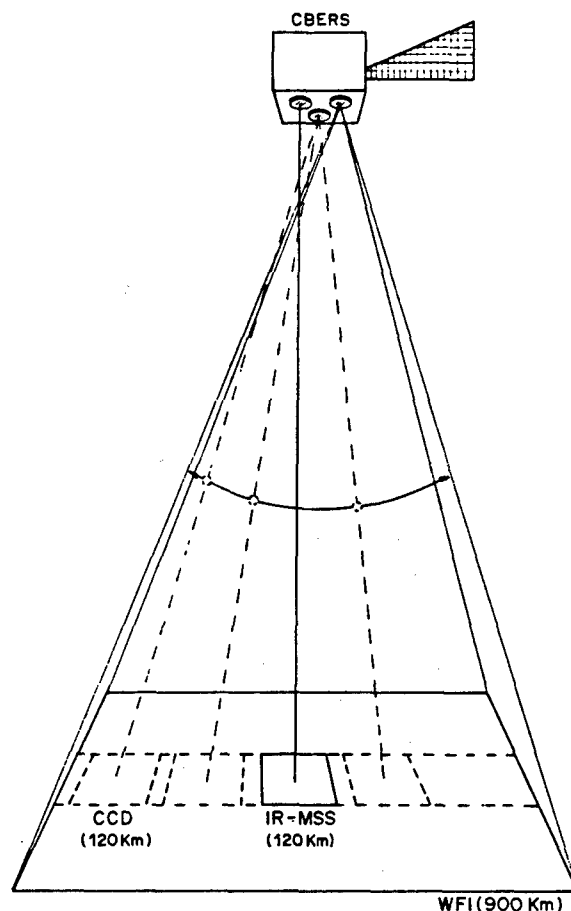


FIGURE 4.76 ZI YUAN/CBERS SATELLITE.



TABLE 4.4 NON-RECOVERABLE PRC EARTH OBSERVATION SYSTEMS.

SYSTEM	FIRST FLIGHT	MEAN ALTITUDE, KM	INCLINATION, DEG	SENSOR BANDS $\mu\text{M}$	RESOLUTION
FENG YUN 1	1988	900	99	0.43-0.53 0.53-0.58 0.58-0.68 0.73-1.10 10.5-12.5	1.08 KM / 4 KM
FENG YUN 2	1995	36000	0	0.50-1.05  5.7-7.1 10.5-12.5	1.25 KM  5 KM
ZI YUAN 1 (CBERS)	1996	800	98.5	0.45-0.52 0.51-0.73 0.52-0.59 0.63-0.69 0.77-0.89  0.5-1.2 1.55-1.75 2.08-2.35  10.4-12.5 0.63-0.69 0.77-0.89	20 M      80 M   160 M 250 M
PROPOSED	TBD	770	98.5	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90  1.55-1.75 3.55-3.95 10.5-12.5	100 M     300 M

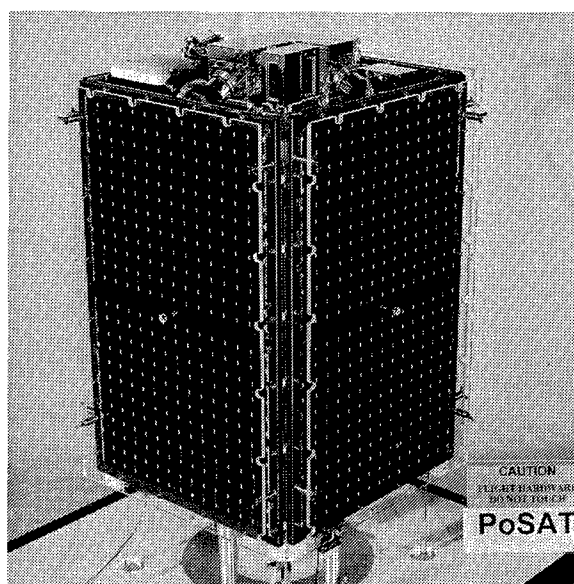


FIGURE 4.77 PoSAT-1 SATELLITE.

1.25 km and 5.0 km, respectively. A water vapor sensor will also be carried. The first Feng Yun 2 satellite was undergoing final check-out on 2 April 1994 before being mated to its launch vehicle when a fire and explosion erupted, destroying the vehicle, killing one worker, and injuring 20 or more others. A second Feng Yun 2 spacecraft was not expected to be ready until late 1995 at the earliest (References 625-631).

Since 1986 PRC and Brazil have been developing, based on Chinese research with the Shi Jian 3 project, a joint Earth observation spacecraft, commonly referred to as CBERS (China-Brazil Earth Resources Satellite) but also known in PRC as Zi Yuan (Earth Resources). PRC is contributing approximately 70% of the program costs for two spacecraft scheduled for launch in 1996 and 1998-1999, respectively. The 1,450-kg spacecraft will have

overall dimensions of 2 m by 3.3 m by 8.3 m with a 1.1 kW capacity, single solar array and will operate in an 800-km sun-synchronous orbit with a 26-day repeating groundtrack pattern.

The Earth observation payload (Figure 4.76) will include three primary sensors (the first two of Chinese origin):

- CCD Camera: Five bands (0.51-0.73  $\mu\text{m}$ , 0.45-0.52  $\mu\text{m}$ , 0.52-0.59  $\mu\text{m}$ , 0.63-0.69  $\mu\text{m}$ , and 0.77-0.89  $\mu\text{m}$ ); 20-m resolution; 113 km swath;
- IR Multi-Spectral Scanner: Four bands (0.50-1.10  $\mu\text{m}$ , 1.55-1.75  $\mu\text{m}$ , 2.08-2.35  $\mu\text{m}$ , and 10.40-12.50  $\mu\text{m}$ ); 80-160-m resolution; 120-km swath;
- Wide-Field Imager: Two bands (0.63-0.69  $\mu\text{m}$  and 0.76-0.90  $\mu\text{m}$ ); 260-m resolution; 900-km swath.

Zi Yuan will also carry a Data Collection System and a Space Environment Monitor (Reference 632).

Chinese spacecraft designers are also investigating the potential of a constellation of several low-mass, LEO spacecraft to fulfill remote sensing objectives. One concept envisions seven coplanar spacecraft of less than 250 kg each in a 770-km, sun-synchronous orbit. Each spacecraft would carry 4-channel CCD sensors capable of 400-km swath widths and 100-m ground resolution (Table 4.4). Total payload mass (camera system, converters, power supply, etc.) is budgeted for only 10 kg. A cooled, multi-channel infrared camera system with a mass of 40-50 kg is also being considered but may require separate spacecraft platforms (Reference 633).

#### 4.3.10 Portugal

Portugal's first satellite, PoSAT-1, was launched on 26 September 1993, as a piggy-back payload on an Ariane LEO mission. Built by the UK's University of Surrey on a SSTL microsatellite bus, PoSAT-1 (Figure 4.77) was inserted into an orbit of 793 km by 806 km at an inclination of 98.7°. One of the central payloads on this 50-kg multi-mission satellite was the Earth Imaging System, consisting of "two CCD imagers, two lenses, and a Transputer Data Processing Experiment to provide on-board image processing and data compression" (Reference 634). The two different imagers permitted a wide-field capability with 2-km resolution or a narrow-field capability with 200-m resolution. Within a few months the small spacecraft

had already returned more than 100 images of the Earth (References 634-636).

#### 4.3.11 Russian Federation

The Russian Federation continues to operate the most comprehensive and diverse set of Earth observation satellites in Eurasia. Eight major systems were active during the period, including the first Russian GEO meteorological satellite. Earth observation and remote sensing remain missions of great importance to the Russian Federation but have been vulnerable to budget cuts in the current fiscally constrained national space program. Although the large number of new systems proposed in the late 1980's and early 1990's are unlikely to materialize, some improved variants of existing systems as well as a few new satellite designs are anticipated during the second half of this decade. For convenience, these systems are divided in this section into the general categories of meteorology, oceanography, and multi-purpose.

Since the inception of the Soviet meteorological program in 1964 and the official debut of the Meteor 1 spacecraft in 1969, the USSR/Russian Federation has operated a single, integrated space-based network designed to meet all civilian, military, and governmental requirements. In 1992 the responsibility for program management of the meteorological program transitioned from the USSR State Committee on Hydrometeorology (GOSKOMHYDROMET) to the newly established Committee on Hydrometeorology of the Russian Ministry of Ecology and Natural Resources. Similarly, the All-Union Research Institute for Electromechanics (VNI-IEM), which has produced Meteor spacecraft for a quarter century, was renamed the All-Russian Electromechanical Scientific Research Institute (References 637-638).

Russian Meteor satellites make possible the creation of atmospheric temperature and humidity profiles, penetrating radiation profiles, sea-surface temperature readings, sea-ice condition charts, snow-cover limit charts, cloud and surface images in the visible and infrared, and cloud-top height charts. The well-known visible images have been transmitted according to the international automatic picture transmission (APT) format since 1971 and are available on carrier frequencies of 137.300 MHz, 137.400 MHz, and 137.850 MHz (FM,  $\pm 50$  KHz bandwidth, two lines per second).

Between 1975 and 1994 21 Meteor 2 spacecraft (not including the apparent Meteor 2 failure designated Kosmos 1066) served as the primary space-based meteorological network. Originally launched by the Vostok booster into nominal orbits of 850 km by 900 km at an inclination of 81.3°, during 1982-1984 the Meteor 2 satellites were transferred to the Tsyklon-3 booster and a new orbital regime of 940 km by 960 km with an inclination of 82.5°.

The approximately 1,300 kg spacecraft carried a modest array of scanning telephotometers, scanning IR radiometers, and a radiation measurement complex (Figure 4.78). Two scanning, single-band (0.5-0.7  $\mu\text{m}$ ) telephotometers, one with a 2,100-km swath width and one with a swath width of 2,600 km, feature ground resolutions of 2 km and 1 km, respectively. A single-band (8-12  $\mu\text{m}$ ) IR radiometer provides 8-km resolution over a 2,800-km swath, while an 8-channel IR radiometer (11.1-18.7  $\mu\text{m}$ ) collects only 37-m resolution over a 1,000-km swath.

The last of the Meteor 2 series spacecraft was launched on 31 August 1993 as Meteor 2-21 (Reference 639). The spacecraft also carried the Italian Temisat micro-satellite as a piggy-back payload designed to collect and retransmit environmental data from terrestrial sensors. Temisat was ejected shortly after reaching orbit. From Western interceptions of Meteor 2-21's transmissions, the spacecraft did not perform as well as earlier vehicles in the series, particularly with regard to image quality and stable signal strength. The spacecraft operated through the end of 1994 on 137.400 MHz and 137.850 MHz, switching when required to avoid interference with other Russian Earth observation space-

craft. No other Meteor 2 spacecraft were apparently operational during 1993-1994.

The Meteor 3 program began with the launch of Meteor 3-1 in 1985 after the prototype spacecraft (Kosmos 1612) was lost due to a launch vehicle failure the previous year. According to documents filed with the World Meteorological Organization, the objectives of the Meteor 3 program are as follows:

- to obtain, on a regular basis, global data on the distribution of cloud, snow, and ice cover and surface radiation temperatures once or twice daily at times close to the synoptic times;
- to obtain, on a regular basis, regional data on the distribution of cloud, snow, and ice cover;
- to obtain, during each communication session, global data on the vertical temperature and humidity distributions in the atmosphere;
- to observe, on a regular basis, information on radiation conditions in near-Earth space globally once or twice a day, and for each orbit in storm conditions" (Reference 640).

To eliminate low latitude coverage gaps, the altitude of Meteor 3 satellites was increased 250 km in comparison with the Meteor 2 network, i.e., approximately 1,200 km circular orbits with an inclination of 82.5°. The higher altitude provides a wider ground swath for the same instrument angular field-of-view. All Meteor 3 spacecraft are launched by the Tsyklon-3 booster from the Plesetsk Cosmodrome.

Although very similar to its predecessor, the Meteor 3 satellite incorporates several new improvements and capabilities. Total spacecraft mass is 2,150-2,250 kg with a payload of 500-

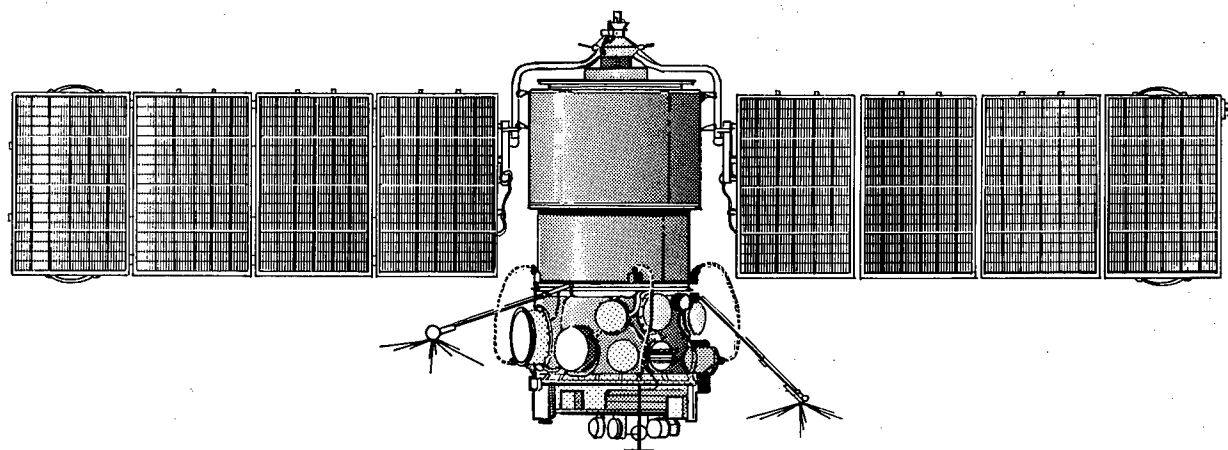


FIGURE 4.78 METEOR 2 SATELLITE.

700 kg in a volume of 0.7 m<sup>3</sup>. The spacecraft (Figure 4.79) is essentially a vertically oriented cylinder with a maximum diameter of slightly more than 1 m and a height of about 1.5 m which supports a payload equipment truss at the bottom, a gravity gradient stabilization system on top, and two movable solar arrays (~1.5 m tall by 3.5 m wide). The spacecraft bus is maintained at standard temperatures and pressures and is fed a total output power from the solar arrays of 500 W. The design lifetime is two years.

The payload truss is an innovation over the Meteor 2 satellite design which facilitates the addition of new and experimental instruments. Table 4.5 details a typical Meteor 3 satellite payload suite. The principal telephotometer produces an image size of 195 mm by 290 mm which is scanned at 3.8 lines per mm with at least 12 gray levels. Similarly, the IR radiometer image of 148 mm by 290 mm is scanned at 1 line per mm with at least 9 gray levels. The 10-channel spectrometer includes one band for water vapor, six bands for carbon dioxide, one band for ozone, and two bands about 11  $\mu$ m. The experimental Ozon-M spectrometer is designed to measure total ozone content and vertical ozone distribution in individual regions (References 640-642). In addition to 137-138 MHz direct transmissions, data is also beamed to Earth at 466.5 MHz (FM,  $\pm 120$  KHz bandwidth, 10 W output power) in a "store and forward" mode. The primary ground stations are located at Moscow/Obninsk, Novosibirsk, and Khabarovsk.

Meteor 3-5 (August, 1991) continued to operate during 1993-1994, but its US TOMS (Total Ozone Mapping Spectrometer) developed problems in May, 1993, and failed entirely

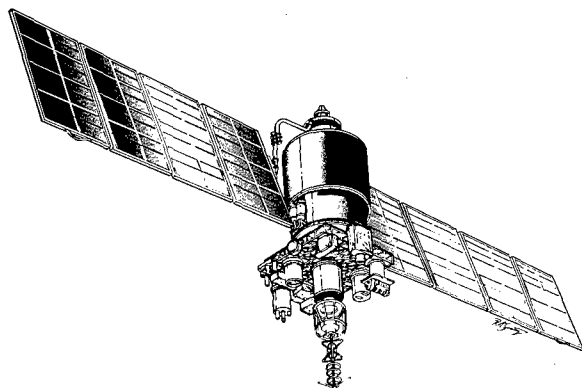


FIGURE 4.79 METEOR 3 SATELLITE.

in late 1994. However, the data returned by the 30-kg instrument, particularly over the south polar region was exceptionally valuable (References 643-652). Working with Meteor 3-5 during 1993 were Meteors 3-3 and 3-4, but both had come to the end of their useful lives as the year came to a close.

The only new Meteor 3 mission undertaken during the period was Meteor 3-6, launched on 25 January 1994. The newest member of the constellation was inserted into an orbital plane 60° to the west of Meteor 3-5's plane. In addition to carrying the German TUBSAT B as a releasable piggyback payload, Meteor 3-6 included an integrated French payload called SCARAB (Scanner for Radiation Budget) and a German PRARE (Precision Range and Range Rate Experiment) instrument. The French radiometer was designed to study the Earth's radiation budget over an extended period of time and to measure the effect of clouds on the greenhouse phenomenon. A second SCARAB instrument is manifested on a Meteor spacecraft to be launched in 1996. The German PRARE was similar to the instrument carried on ESA's ERS-1 satellite (References 653-657).

The last Meteor 3 is scheduled for 1995 and will be followed in 1996 by the first of the Meteor 3M class. The overall mass of the spacecraft will be increased to 2,500 kg, including a larger payload of up to 900 kg. In addition, the average daily power available will nearly double to 1 kW, and the spacecraft stabilization accuracy will be improved by an order of magnitude. Pointing accuracy will also be improved, as well as satellite design lifetime which will reach three years. The store and forward transmission mode will be converted from the current 466.5 MHz analog to 1.69-1.71 GHz digital. The 1.4 m diameter, 2.2 m long spacecraft bus will carry a payload truss (like Meteor 3) with dimensions of 1,800 mm by 1,600 mm by 270 mm. High-temperature ammonia thrusters (0.147 N) will be used for adjustments of the basic 900 km by 950 km orbit. Originally slated for an orbital inclination of 82.5°, Meteor 3M may also be inserted into sun-synchronous orbits by the new Rus launch vehicle. In 1994 NASA was negotiating with the Russian Space Agency to fly a SAGE III (Stratospheric and Aerosols and Gas Experiment) instrument on a 1998 Meteor 3M and a new TOMS payload on a flight in the year 2000 (References 641, 656, 658-660).

TABLE 4.5 TYPICAL METEOR 3 INSTRUMENT SUITE.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS $\mu\text{M}$	GROUND SWATH KM	GROUND RESOLUTION KM	TRANSMISSION MODE
SCANNING TELEPHOTOMETER	1	0.5-0.7	2600	1.0 x 2.0	DIRECT
SCANNING TELEPHOTOMETER	1	0.5-0.7	3100	0.7 x 1.4	STORE/DUMP
SCANNING IR-RADIOMETER	1	10.5-12.5	3100	3 x 3	DIRECT
SCANNING IR-RADIOMETER	10	9.4-19.68	1000	42	STORE/DUMP
UV-SPECTROMETER	8	0.25-0.38	200	3-5 IN ALTITUDE	STORE/DUMP
MULTI-CHANNEL UV-SPECTROMETER (OZON-M)	4	0.25-0.29 0.37-0.39 0.60-0.64 0.99-1.03	- - -	2 IN ALTITUDE	STORE/DUMP
RADIATION MEASUREMENT COMPLEX (PMK)	REGISTRATION OF FLOW DENSITY: 0.15-3.1 MeV (ELECTRONS) 1-600 MeV (PROTONS)				STORE/DUMP

The year 1994 witnessed the long-awaited debut of the Geostationary Operational Meteorological Satellite (GOMS) system of Elektro spacecraft. Originally proposed for a maiden flight in 1978-1979, GOMS has suffered both technical and budgetary problems. The objectives of the program, as stated in 1991, are as follows:

- to acquire, in real time, television images of the Earth surface and cloud within a radius of 60° centered at the sub-satellite point in the visible and IR regions of the spectrum;
- to measure temperature profiles of the Earth surface (land and ocean) as well as cloud cover;
- to measure radiation state and magnetic field of the space environment at the geostationary orbital altitude;
- to transmit via digital radio channels television images, temperature and radiation and magnetometric information to the Main and regional data receiving and processing centers;
- to acquire the information from Soviet and international data collection platforms (DCPs), located in the GOMS radio visibility, and to transmit the obtained information to the main and regional data and processing centers;
- to retransmit the processed meteorological data in the form of facsimile or alphanumeric

ical information from the receiving and processing centers to the independent receiving stations via satellites;

- to provide the exchange of high-speed digital data (retransmissions via the satellite) between the Main and regional centers of the USSR State Committee for Hydrometeorology;
- to call for the data collection platforms to transmit the information to the satellite." (Reference 661)

The GOMS network will eventually consist of three spacecraft spaced 90° apart in the geostationary ring: at 14° W, 76° E, and 166° E. Each 2.6-metric-ton spacecraft will have a payload capacity of 650-900 kg with an estimated operational lifetime of at least three years. The satellites will be 3-axis-stabilized and receive a maximum of 1.5 kW (900 W for the payload) produced by two rectangular solar arrays (Figure 4.80). Twelve communications channels will link the spacecraft to the receiving and processing centers, the independent data receiving center, and the data collection platforms. The main data receiving and processing center is in the Moscow region while two regional centers are located at Tashkent and Khabarovsk (Figure 4.81).

The Elektro spacecraft instrument suite is summarized in Table 4.6, although the 6-7  $\mu\text{m}$  scanning radiometer might not appear until the

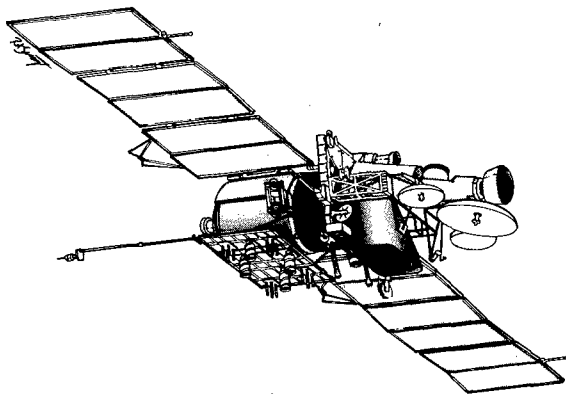


FIGURE 4.80 ELEKTRO SATELLITE.

second mission. The telephotometer is limited to a total of 24 frames per day (each framing session lasts 30 minutes of which 15-20 minutes is imaging time), and only 4-5 frames can be successively taken at the 30 minute per-

frame imaging rate. This high frame rate will normally be employed around 0000 and 1200 GMT, in part, to permit the calculation of wind speed and direction data. DCP information will be collected and transmitted at three-hour intervals each day, i.e., 0300 GMT, 0600 GMT, etc. (References 661-663).

Elektro 1 was finally launched on 31 October 1994. Malfunctioning of the local vertical sensor and the attitude control system delayed the positioning of the spacecraft (Figure 4.82) at its intended location of 76° E, but by early December Elektro 1 was on station. However, problems with the local vertical sensor continued to plague the spacecraft, and useful images were not immediately available (References 664-667).

In the late 1970's the USSR began testing a series of new instruments which would complement the standard meteorological payloads while at the same time would provide specific data on ocean and ice conditions. The heavy

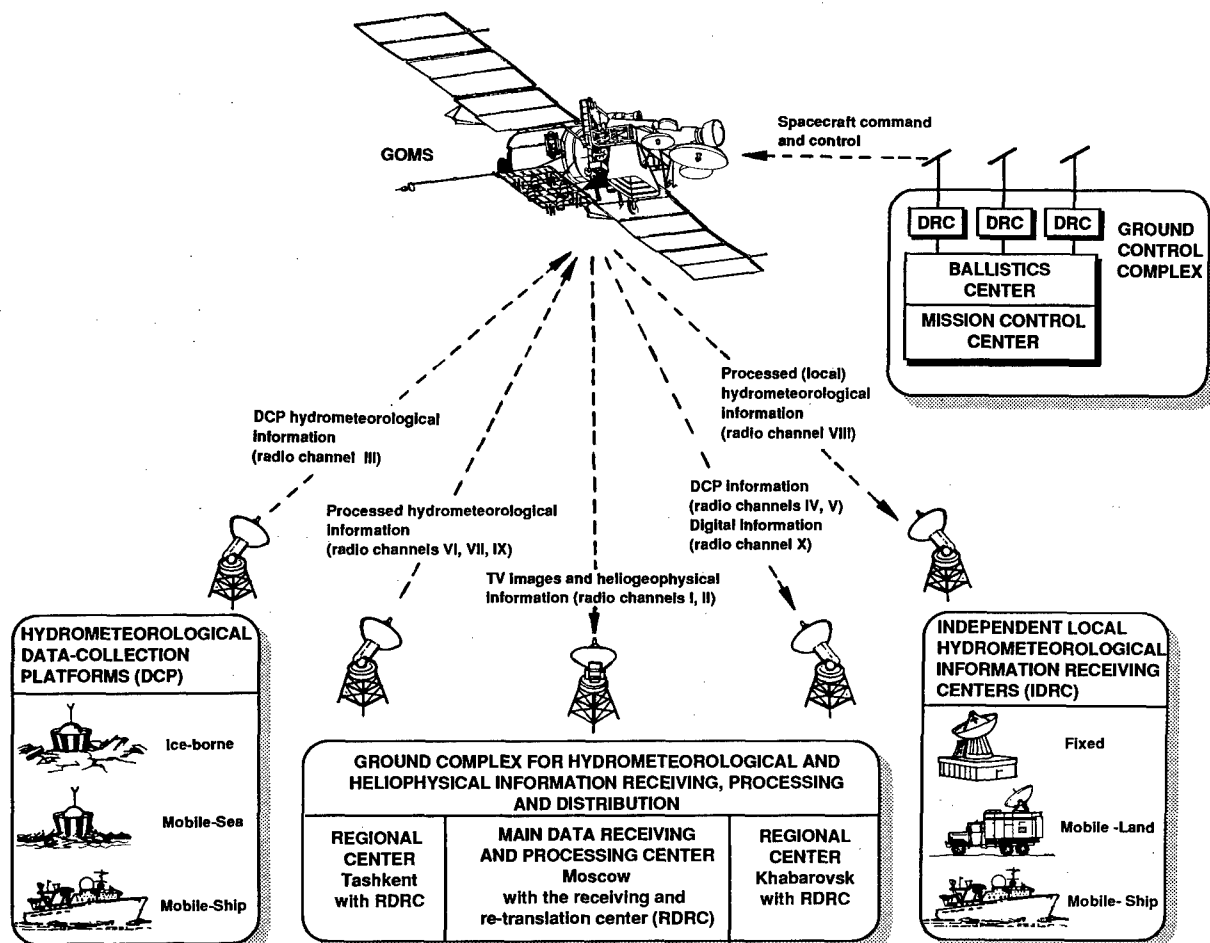


FIGURE 4.81 GOMS METEOROLOGICAL NETWORK.

TABLE 4.6 ELEKTRO INSTRUMENT SUITE.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS $\mu\text{M}$	GROUND RESOLUTION KM	SCAN LINES PER FRAME
SCANNING TELEPHOTOMETER	1	0.4-0.7	1.25	8000
SCANNING IR-RADIOMETER	1	10.5-12.5	6.5	1400
SCANNING IR-RADIOMETER	1	6-7	6.5	1400
RADIATION MEASUREMENT COMPLEX (PMK)	REGISTRATION OF FLOW DENSITY: 0.04-1.7 MeV (ELECTRONS) 0.5-90 MeV (PROTONS) 5-12 MeV (ALPHA) > 600 MeV (COSMIC RADIATION)			

reliance of the USSR on its merchant marine fleet for both domestic and international commerce, particularly in the northern latitudes which are subject to extreme environmental conditions, prompted the State Committee on Hydrometeorology to develop specialized spacecraft capable of providing direct operational assistance to ships at sea as well as to a

host of other government agencies and civilian and military organizations.

After testing various equipment on four spacecraft (Kosmos 1076, Kosmos 1151, Interkosmos 20, and Interkosmos 21) launched during 1979-1981, the first prototype Okean satellite (Okean-OE) was orbited in 1983 as Kosmos 1500 and was followed by Kosmos 1602 (1984), Kosmos 1766 (1986), and Kosmos 1869 (1987). The first operational spacecraft (Okean-O) was launched in 1988 as Okean 1 and was joined in 1990 by Okean 2.

This Okean-O program is designed

- “• to estimate the potential reserves of the energy of tides and the accumulated energy of solar radiation;
- to study the World Ocean as a global damper and regulator of heat and moisture content of the atmosphere;
- to detect zones of upwelling and higher bio-productivity;
- to study subsurface circular eddies and their effect on the formation of destructive cyclones and typhoons;
- to ensure the safety of navigation and control of the ice situation in the Arctic and Antarctic;
- to study the dynamics of sea currents, and the processes of self-purification of sea water and cleansing of river effluents; and
- to control the intensity of pollution of the oceans with oil and oil product discharges.”

Okean spacecraft with their electro-optical and radar sensors are designed and manufactured by the Ukrainian Yuzhnoye Scientific Production Association of Dnepropetrovsk and are described in detail in Section 4.1.13. Perhaps the last Russian-sponsored Okean spacecraft,

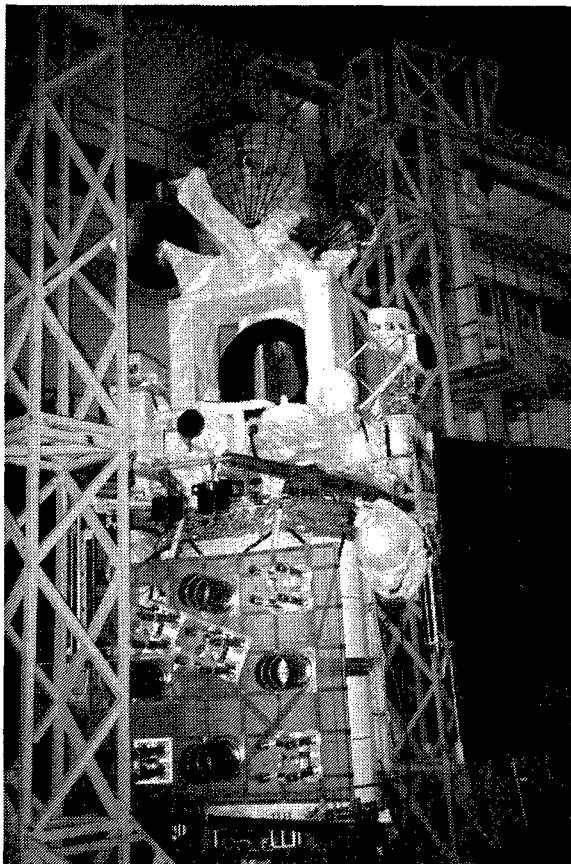


FIGURE 4.82 ELEKTRO 1 IN INTEGRATION.

Okean 4, was launched on 11 October 1994 by a Tsyklon-3 booster from the Plesetsk Cosmodrome into an orbit of 632 km by 666 km at an inclination of 82.5°. Okean 4's predecessor, Okean 3, had ceased working in January of 1994 (References 668-669).

In addition to the meteorological and oceanographic satellites described above, the Russian Federation has operated seven different types of spacecraft since 1991 to perform a wide variety of global remote sensing observations. More advanced spacecraft are already in the design and development phase for possible missions later in this decade. However, together the satellites represent a level of redundancy which suggests that, in the difficult financial conditions now present in the Russian Federation, not all spacecraft classes will continue to be supported.

The Resurs-O program, which is analogous to the US Landsat program, became operational in 1985 after more than ten years of on-orbit testing. Designed and manufactured by the All-Union Research Institute for Electromechanics, the Resurs-O1 spacecraft, not surprisingly, closely resemble the Meteor series of satellites from which they were derived. In fact, the Resurs-O development program utilized two Meteor satellites (Meteor 1-18 and Meteor 1-25) and five Meteor-Priroda vehicles (1977-1983) to perfect the instruments and techniques finally adapted for Resurs-O1. The Meteor-Priroda satellites also marked the first use of sun-synchronous orbits by the USSR.

Program management for the Resurs-O effort was originally the responsibility of the State Committee on Hydrometeorology. In 1989 the Planeta NPO was formed under this organization to consolidate the meteorological and remote sensing satellite systems of the USSR. Subsequently, the Planeta NPO, the All-Union Research Institute of Electromechanics, and the Space Instrument Building NPO, which was responsible for many of the payload instruments, formed the Soviet Association for Earth Remote Sensing (SOVZOND) to promote Resurs-O products on a commercial basis.

Resurs-O spacecraft are placed into nominal orbits of 630 km altitude and an inclination of 98°. Each mission is conducted to ensure that the spacecraft's descending node will occur between 10:00 and 10:30 a.m. local sun time, thereby providing excellent lighting conditions

for the complex sensor suite. The objectives of the Resurs-O program are as follows:

- to obtain in both real-time and store-and-forward modes multispectral sensor information with medium and high resolution in visible and IR bands to provide data for land and ocean states in any region of the globe;
- to obtain in the same modes the all-weather relay images of the land ocean with medium resolution;
- to process the obtained data and images, and to perform their radiometric, geometric and geographical correction;
- to represent and distribute the obtained data in the form of single-spectral and synthesized multispectral images on the photos, negatives, and digital recordings on the various media (tapes, diskettes); and
- to obtain and disseminate thematic maps and charts concerning various aspects of Earth natural resources exploration, environmental control and ecological monitoring" (Reference 670).

The Resurs-O1 spacecraft bus is almost identical to that of the Meteor 3 vehicle with a total mass of 1,840-1,910 kg, including a payload of up to 600 kg (Figure 4.83). The spacecraft diameter is 1.4 m with an overall height of 6.4 m and a solar array span of 11.6 m. The payload support structure at the base of the spacecraft is tailored for each mission to accommodate the specific instruments to be carried. For example, of the three primary instruments available (Table 4.7), the first Resurs-O1 (Kosmos 1689) was out-fitted with two MSU-E, one MSU-SK, and one MSU-S devices, while the second Resurs-O1 (Kosmos 1939) omitted the MSU-S and carried two MSU-E and two MSU-SK. The 30-kg MSU-E employs an electro-optical CCD scanner for high resolution and can be used in pairs to provide a continuous 80-km wide swath. On the other hand, the mechanical MSU-SK scanner weighs 60 kg and combines a lower resolution capability with a much wider swath. (References 183-192).

The primary data collection and processing stations for Resurs-O are the same as for Okean: Moscow, Novosibirsk, and Khabarovsk. The principal data transmission link is also similar at 466.5 MHz. A standardized small receiving station, utilizing a 2.5 m diameter antenna and the Spektr-DK01 system, has been designed for use with both Okean and Resurs-



TABLE 4.7 RESURS-O1 INSTRUMENTS FLOWN.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS $\mu\text{M}$	GROUND SWATH KM	GROUND RESOLUTION M
MSU-SK	5	0.5-0.6	600	170
		0.6-0.7		170
		0.7-0.8		170
		0.8-1.1		170
		10.4-12.6		600
MSU-E	3	0.5-0.6	45 ( $\pm 350$ km off nadir)	45
		0.6-0.7		
		0.8-0.9		
MSU-S	2	0.58-0.7	1380	240
		0.7-1.0		

O spacecraft when the data links are upgraded to the new 8.2 GHz system (Reference 193).

Kosmos 1939 (April, 1988) had far exceeded its design lifetime of one year and was still operational when it was joined by Resurs O-1 on 4 November 1994. Unlike earlier Resurs-O1 type spacecraft which had been launched by Vostok boosters from the Baikonur Cosmodrome, Resurs O-1 was launched by a Zenit-2 booster and was inserted into an orbit of 661 km by 663 km with an inclination of 98.0°. The spacecraft mass of 1,907 kg was slightly higher than earlier models and included an attached German SAFIR-R payload (Section 4.1.4). The principal Earth observation sensors were MSU-SK and MSU-E instruments along with an experimental PVM-E local vertical sensor (References 681-687).

Originally scheduled to replace Resurs-O1 in late 1992, Resurs-O2 represents an evolutionary improvement of the Resurs-O system which adds both a synthetic aperture radar

(SAR) and a microwave radiometer capability (Figure 4.84 and Table 4.8). Resurs-O2 not only will be heavier (2,400 kg with a payload of 900 kg) but also may be placed in a higher, 830-km orbit to increase its coverage potential. A Resurs-O2 variant specifically designed for Arctic surveys is also under consideration.

The Resurs-O2 payload will be able to draw up to 800 W daily with a peak power of 2 kW. The data transmission system will operate at 8.2 GHz to the main receiving and data processing center at Moscow and the regional centers at Novosibirsk, Tashkent, and Khabarovsk as well as with smaller, local stations (Figure 4.85). On-board data storage capacity will also be increased markedly.

While the first SARs have yet to fly on Resurs-O2, the Russian experts have already gained experience with this advanced technology under the Almaz program. The basic Almaz spacecraft was first designed in the 1960's under Chief Designer Vladimir Chelomei as a military manned space station. Almaz was flown three times during the 1970's (Salyut 2 in 1973, Salyut 3 in 1974, and Salyut 5 in 1976) and its civilian derivative was used for the remaining Salyut missions. The fourth Almaz vehicle was the first to be equipped with a large, high resolution SAR and was scheduled for launch in 1981. However, a dispute between Chelomei and Minister of Defense Ustinov led to a grounding of the spacecraft until 1986 when it was finally launched but failed to reach orbit due to a failure of its Proton booster. A duplicate satellite was later flown during 1987-1989 as Kosmos 1870 (Reference 688).

An improved Almaz, officially designated Almaz 1, was launched on 31 March 1991

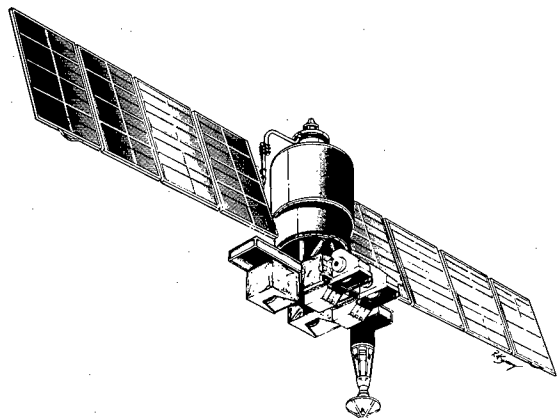


FIGURE 4.83 RESURS-O1 SATELLITE.

TABLE 4.8 PROPOSED RESURS-O2 INSTRUMENT SUITE.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS	GROUND SWATH, KM*	GROUND RESOLUTION*
MSU-SK2	5	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.7-0.8 $\mu\text{m}$ 0.8-1.1 $\mu\text{m}$ 10.4-12.6 $\mu\text{m}$	600	170 m 170 m 170 m 170 m 600 m
MSU-E2	3	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.8-0.9 $\mu\text{m}$	45 ( $\pm 350$ km off nadir)	20 m
RLS-BO SYNTHETIC APERATURE RADAR	1	23 cm	100	200 x 200 m (on-board processing)  50 x 200 m (ground processing)
DELTA-2P MULTI-CHANNEL MICROWAVE RADIOMETER	4	0.8 cm 1.35 cm 2.2 cm 4.5 cm	1200	17 km 30 km 45 km 90 km

\* These values dependent on operational altitude.

(eight months after its target date) into an initial operational orbit of approximately 270 km with an inclination of  $72.7^\circ$ , slightly higher than the  $71.9^\circ$  inclination of Kosmos 1870. The primary manufacturer and integrator of Almaz 1 was the Machine Building NPO using the former Chelomei facilities in the Moscow suburb of Reutov. The principal radar payload was contributed by the Vega NPO. The observation program was prepared with the assistance of the State Com-

mittee on Hydrometeorology, the State Geodesy Committee, the Ministry of Nature Management, and the USSR Academy of Sciences.

The initial on-orbit mass of Almaz 1 was 18,500 kg with sufficient propellants to maintain the vehicle at a low altitude for up to two years and to provide for a controlled reentry over a broad ocean area at the end of mission. The spacecraft core consisted of two joined cylinders with a length of 12 m and a maximum diameter of the larger cylinder of 4.2 m. This basic space station structure (similar to Salyut and Mir) has an interior volume of 90 m<sup>3</sup> which is maintained at standard temperatures and pressures.

Attached to the spacecraft bus were two solar panels capable of generating a mean power of 2.4 kW and a peak power of 7.5-10 kW and two 3-piece SAR antennas (1.5 m by 15 m) along either side of the spacecraft. At the forward end of Almaz 1 between the two SAR antennas were two phased-array antennas to permit real time data transfers via a geosynchronous relay satellite. Two small dish command and control and data transmission antennas were located at the aft end of Almaz 1, and a separate data transmission antenna extended

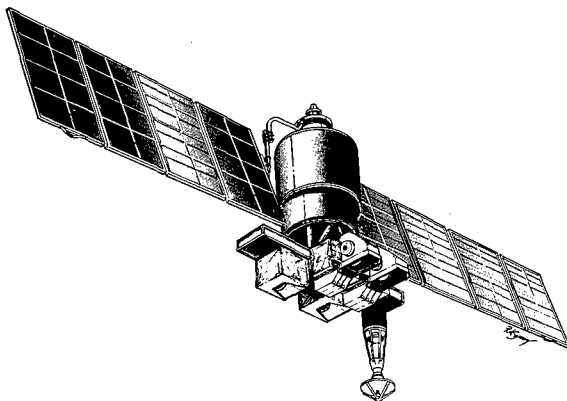


FIGURE 4.83 RESURS-O2 SATELLITE.

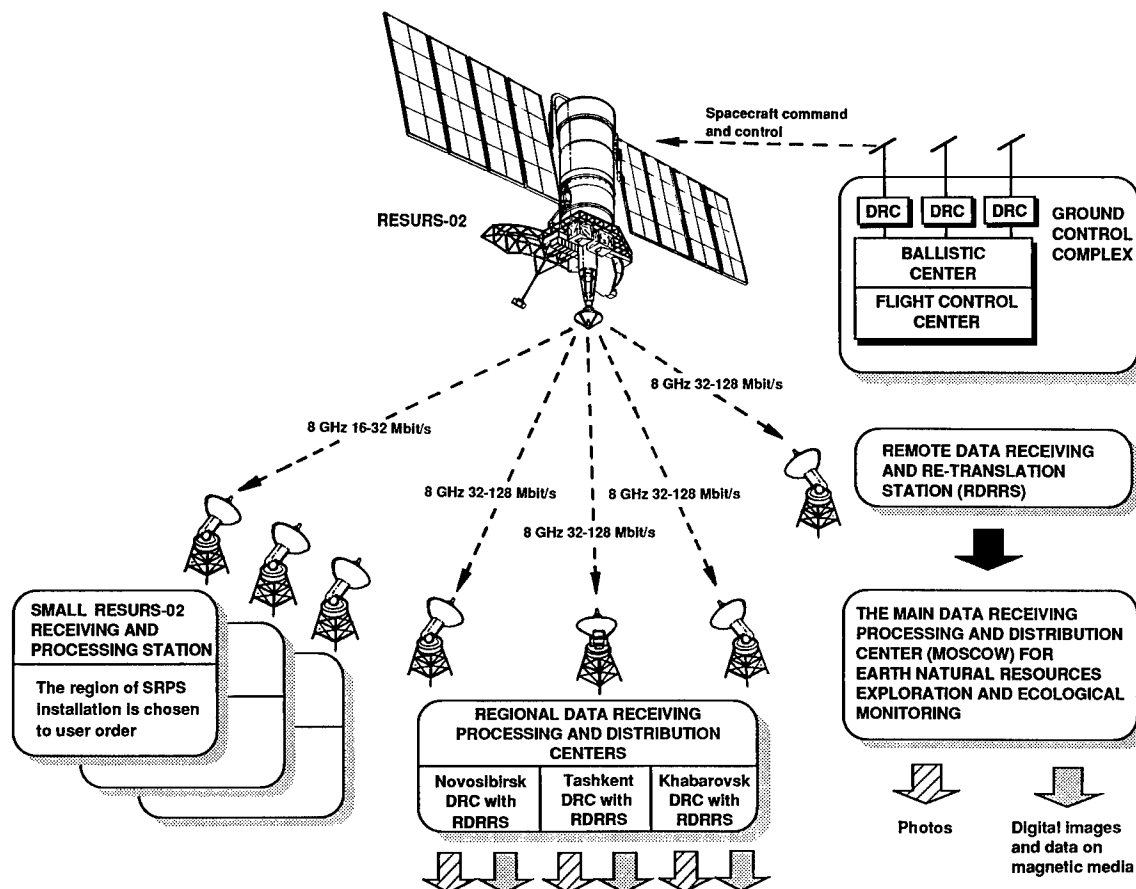


FIGURE 4.85 RESURS-O2 DATA COLLECTION AND DISTRIBUTION NETWORK.

upward from the spacecraft's midsection (Figure 4.86).

Almaz spacecraft can carry a payload of 4-6.5 metric tons. On Almaz 1 this was divided between the SAR and a multi-channel microwave radiometer operating at 6-37.5 GHz with a swath of 600 km and a resolution of 10-30 km. The SAR transmitted at a frequency of 3 GHz with an average power of 80 W and a peak power of 190 kW. A typical radar image covered a region 20-45 km wide and 20-240 km long with a resolution of 15-30 m. However, Almaz 1 could aim its coverage over a swath at least 350 km wide. Unfortunately, the failure of one of the SAR antennas to deploy fully rendered that side inoperable. The main data reception center was located in Moscow region, although designs for data processing stations outside the USSR/CIS with a VAX-11/785, two MicroVAX II's, and four IBM PS/2-80's have been created (References 689-692).

Originally, a second Almaz 1-type spacecraft, with some payload modifications, was to be launched in 1993 on a two-year mission. In

particular, Almaz-1B would carry three synthetic aperture radars: SAR-10 (9.6 cm wavelength, 5-40 m resolution, 25-300 km swath), SAR-70 (70 cm wavelength, 15-60 m resolution, 100-150 km swath), and a 3.6-cm wavelength SAR. Multi-spectral scanners, including MSU-E and MSU-SK, would also be carried as well as a Balkan-2 lidar. However, a lack of funding has postponed the flight of Almaz-1B to late 1997 at the earliest.

Likewise, plans for even more sophisticated and capable Almaz 2 spacecraft (Figure 4.87) have been delayed until near the turn of the

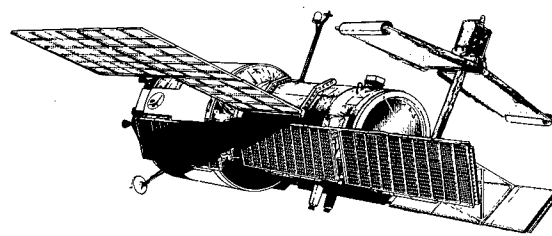


FIGURE 4.86 ALMAZ 1 SATELLITE.

century. Almaz 2's payload mass of 6.5 metric tons would be powered by solar arrays with a maximum beginning-of-life average power rating of 3.8 kW. More than three metric tons of propellants would be available for a mission duration of up to five years at an altitude of 600 km (References 693-703).

One of the oldest and still highly capable methods of performing space-based Earth observations is basic photography in one or more spectral bands with return of the film to Earth for development and analysis. This technique was first perfected in the USSR in 1962 but was not officially converted into a civil-oriented system until 1979. Until recently, two similar types of 3rd generation spacecraft, Resurs-F1 and Resurs-F2, have been flown several times a year for the Russian Ministry of Ecology and Natural Resources. The Resurs-F1 program apparently ended in 1993, and the last Resurs-F2 mission was expected in 1995. Plans to introduce improved Resurs-F1M and Resurs-F2M may be abandoned.

With two missions in 1993, the Resurs-F1 program achieved 50 orbital flights (and two launch failures) during its 14-year operation with missions lasting up to 23 days. Based on the Vostok spacecraft developed in the late 1950's, Resurs-F1 spacecraft were designed and manufactured at the Samara (formerly Kuybyshev) Photon Design Bureau and the Progress Plant both of the Central Specialized Design Bureau. The Resurs-F1 vehicle, launched by the Soyuz-U booster from Plesetsk, is 7 m long with a maximum diameter of 2.4 m and a mass of 6,300 kg and is com-

prised of three major modules (Figure 4.88).

The central portion of the spacecraft is a sphere of 2.3 m diameter and a mass of about 2.4 metric tons containing the photographic apparatus, electronic control equipment, and the recovery system. This section is secured to a 3 m long, 2.4 m wide service and reentry propulsion module with four straps which are released after retrofire. On the opposite end of the recoverable capsule is a 1.9 m by 1 m propulsion unit used for minor orbital adjustments. The propulsion unit is also jettisoned prior to reentry and may carry additional, releasable payloads (up to 75 cm by 90 cm) for secondary missions. Secondary payloads up to 30 kg or more can also be carried inside or outside the recoverable capsule for return to Earth.

Two photographic systems are normally available on Resurs-F1 missions: the SA-20M with a KFA-1000 camera and the SA-34 with its KATE-200 camera. The former operates in two spectral bands (0.57-0.68  $\mu\text{m}$  and 0.68-0.81  $\mu\text{m}$ ) with a ground swath of 80 km and a resolution of 5-8 m. Up to 1,800 frames measuring 300 mm by 300 mm may be taken on each mission. The SA-34 operates in three spectral bands (0.51-0.60  $\mu\text{m}$ , 0.60-0.70  $\mu\text{m}$ , and 0.70-0.85  $\mu\text{m}$ ) with a ground swath of 225 km and a resolution of 15-30 m. The SA-34 has a capacity of 1,200 frames, each 180 mm by 180 mm. All film frames of both systems are etched with codes to identify vital camera parameters, including camera and frame number, film number, focal length, and timing codes (References 704-709).

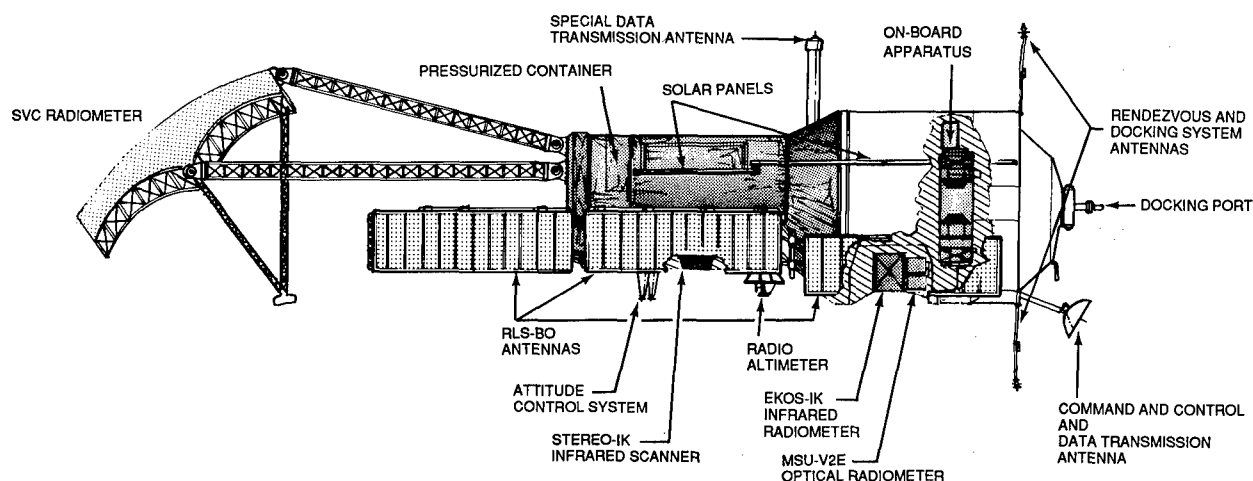


FIGURE 4.87 ALMAZ 2 SATELLITE.

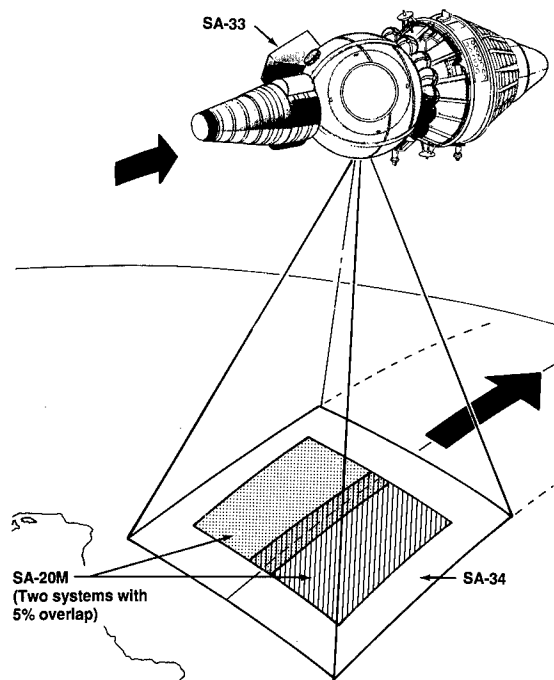


FIGURE 4.88 RESURS-F1 SATELLITE.

Each Resurs-F1 spacecraft carries multiple camera systems. The Priroda 4 payload configuration includes two SA-20M and three SA-34 devices. One of the SA-34's is linked to a SA-33 stellar camera to provide simultaneous star backgrounds for precise geographical location determination. The SA-34 survey regions are aligned with common axes, but the SA-20M cameras are each oriented  $8^\circ$  off nadir for a total separation of  $16^\circ$  between the camera axes, permitting a 5% image overlap when both systems are operated simultaneously. Six modes of operation are possible with 2-5 camera systems operating at one time. Although the maximum spacecraft lifetime is 25 days, the electrical system fed only by storage batteries limits active operations to no more than 14 days. The last two Resurs-F1 missions were flown in 1993 as Resurs-F 18 (June-July) and Resurs-F 19 (August-September), both on 17-day missions.

In 1987 a more capable version of the Resurs-F1, called Resurs-F2, began operations. The most significant improvement was the addition of two small solar arrays attached

to the base of the orbital propulsion unit which permitted active missions for up to a full month (Figure 4.89). The first mission in late 1987 by Kosmos 1906 was not entirely successful, and the spacecraft was intentionally destroyed in orbit. Four more missions were conducted during 1988-1990, followed by three flights in 1991-1992.

The Resurs-F2 photographic system differs from that of its predecessor. The SA-M system with its MK-4 camera combines the high resolution of the SA-20M with the multi-spectral capability of the SA-34. Resurs-F2 offers a ground swath of 150 km with a resolution of 5-8 m in six spectral bands from  $0.40 \mu\text{m}$  to  $0.86 \mu\text{m}$ . As many as 2,700 photographs with image motion compensation and frames 180 mm by 180 mm can be shot on a single mission. The SA-M is also linked to the SA-3R stellar camera which serves the same purpose as the Resurs-F1's SA-33 (References 704-709).

Prior to 1991, Resurs-F2 spacecraft would normally maintain a mean altitude of between 260 km and 270 km, requiring only two orbital maneuvers per 30-day mission. Beginning with Resurs-F 10 (21 May 1991), a new profile was chosen with mean altitudes between 225 km and 235 km but with a corresponding requirement to perform orbital adjustments more frequently, e.g., six times per mission. This pattern had previously been used primarily by the fourth-generation, topographic mapping satellites which debuted in 1981 and are flown at

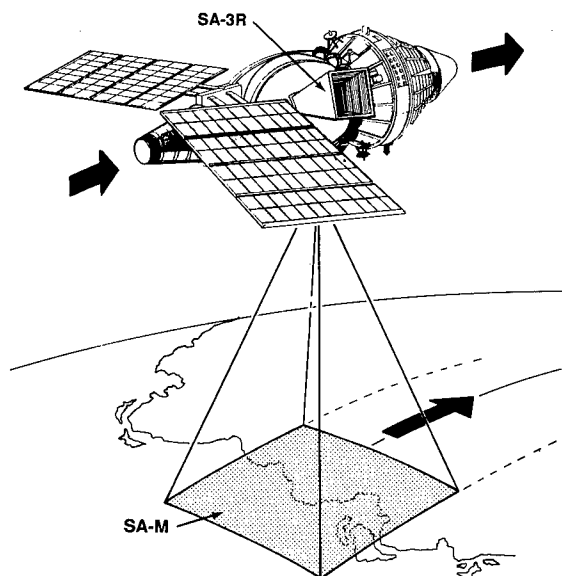


FIGURE 4.89 RESURS-F2 SATELLITE.

inclinations of 65° and 70°. The subsequent Resurs-F2 flights, Resurs-F 13 (21 August 1991) and Resurs-F 14 (29 April 1992), were virtually identical to Resurs-F 10, both in character and duration. Resurs-F 17 (May-June 1993), the only Resurs-F2 of the 1993-1994 period, also followed this pattern.

Reference to a Resurs-F3 spacecraft appeared in 1994, and it now appears that this designation applies to the Resurs-T satellite flown for the Ministry of Defense. The spacecraft is virtually identical to the Resurs-F1 but carries the KFA-3000 camera system with 2-3 m resolutions. Two Resurs-T missions were flown during 1993-1994: Kosmos 2260 (July-August 1993) and Kosmos 2281 (June 1994) (References 708 and 710).

During 1992 the Russian Federation made available to the commercial market Earth observation photography acquired by military photographic reconnaissance satellites. In particular, two types of analog optical images taken by the more modern fourth-generation satellites were made available. Ten-meter resolution stereo photographs taken by the TK-350 camera, which is a product of the Belorussia Optical

Camera Company, cover a region of 180 km by 270 km with 256 gray values. Higher resolution, two-meter photographs from the KVR-1000 camera provide similar gray-level sensitivity but over a much smaller area of 40 km by 40 km (References 711-713). Since these missions remain primarily of a military nature, they are described more fully in Section 6.1.5.

As early as 1989 Russian officials indicated that future civil Earth observation satellites may employ digital electronic transmission techniques in realtime or near-realtime like the current fifth-generation military photographic reconnaissance satellites. This capability may soon be realized under the new Resurs-Spektr program. Resurs-Spektr V spacecraft (Figure 4.90) appear to be modified fifth-generation satellites and reportedly will produce 3-5 m resolution stereo images. Almaz-class phased-array antennas enable downlinks via geostationary relay satellites. A second Resurs-Spektr variant, Resurs-Spektr RI (Figure 4.91), with a side-looking radar has also been proposed (References 714-715). Another possible replacement for the Resurs-F class of spacecraft is an imaging variant of the Kuban spacecraft which has

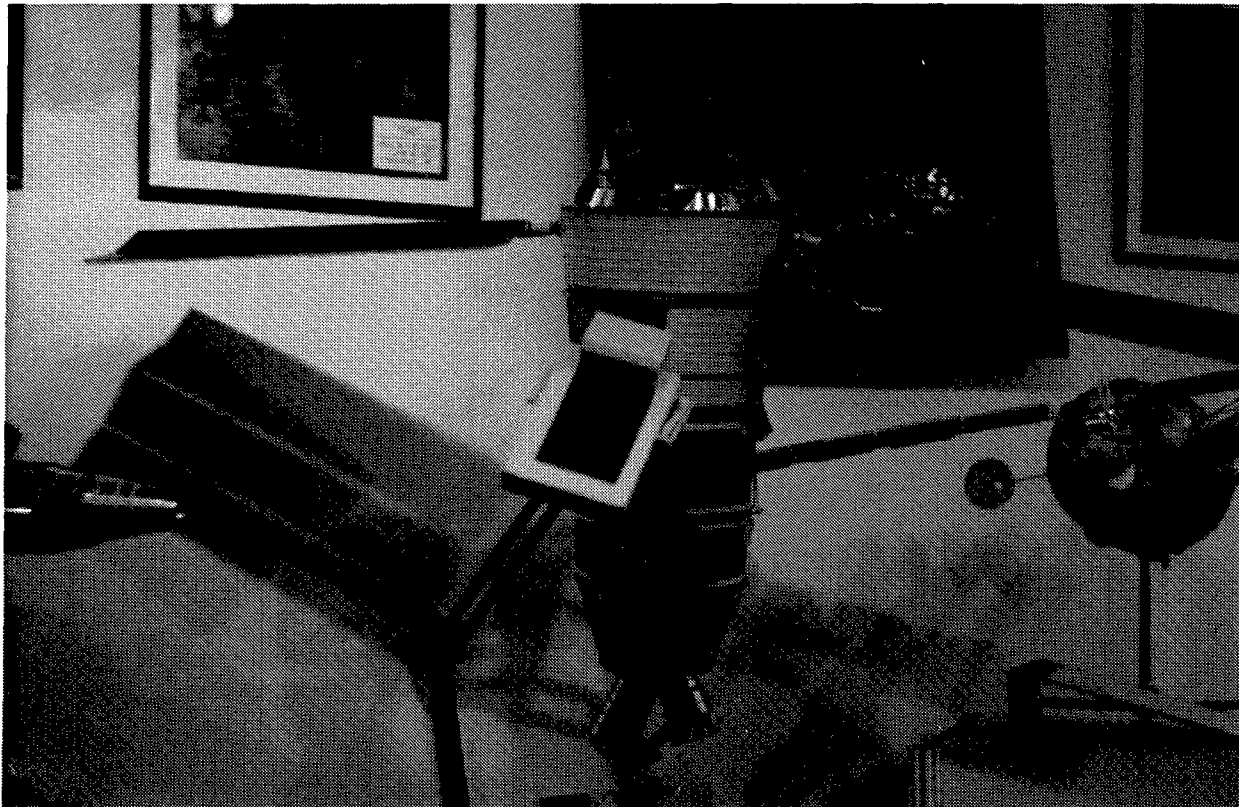


FIGURE 4.90 RESURS-SPEKTR V SATELLITE.

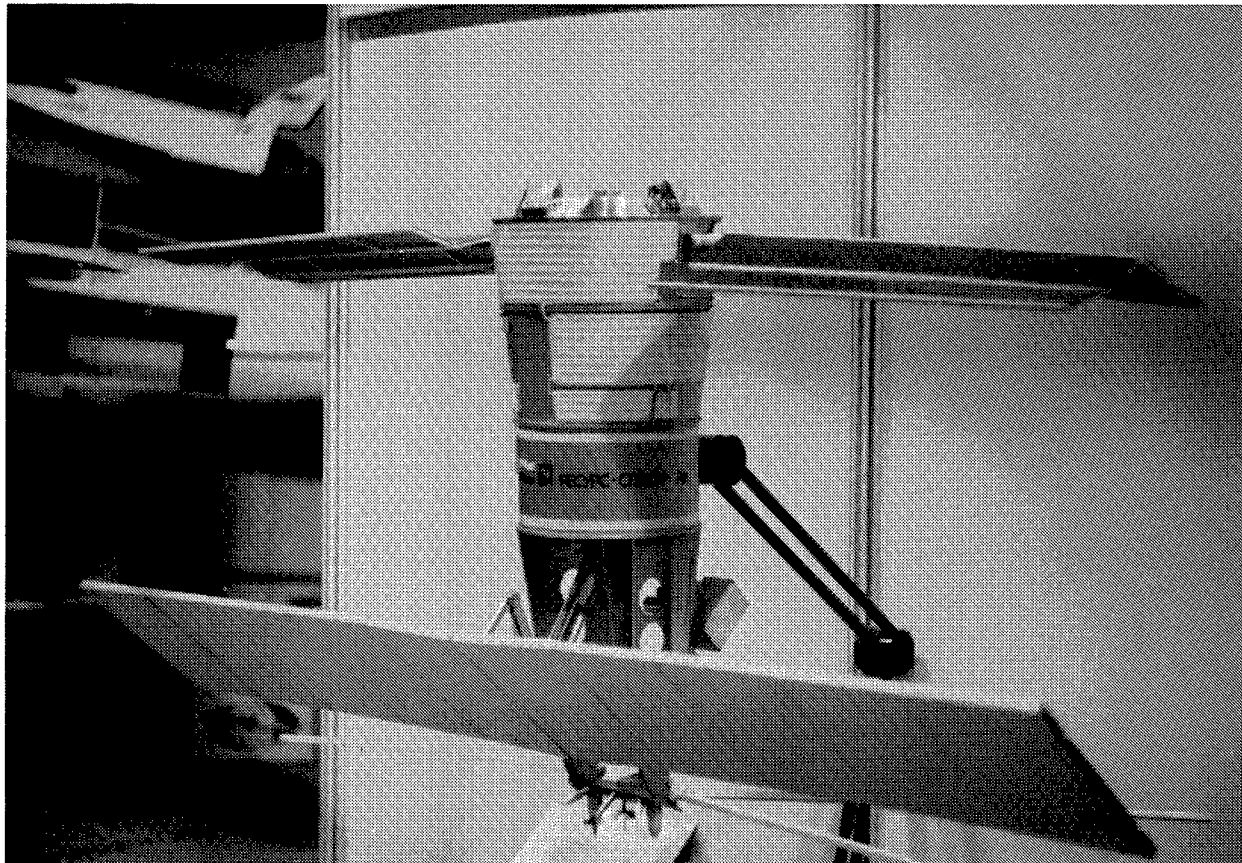


FIGURE 4.91 RESURS-SPEKTR RI SATELLITE.

been under development for several years for microgravity research (Section 4.4.7) (Reference 716).

An extensive suite of Earth observation instruments is currently operational on the Mir space station. Although only a pair of devices were carried aboard Mir at its launch in 1986, sixteen major systems have been deployed to the Mir core module or the Kvant 2 and Kristall auxiliary modules:

Mir Core Module:

- EFO-1 electronic photometer for studies of atmospheric aerosols and dust
- Haselblad camera
- KATE-140 topographic camera (50-m resolution)
- MKS-M multi-band spectrometer (0.4-0.9  $\mu\text{m}$ )
- PCN spectrometer
- Sever topographic camera (used in conjunction with KATE-140)
- Skif spectrometer (0.4-1.1  $\mu\text{m}$ )
- Spektr-256 multi-band spectrometer (256 channels in visible and IR)

- Terra impulse photometer for the study of atmospheric optical emissions

Kvant 2 Module:

- AFM-2 for study of the atmosphere and pollutants
- Gamma 2 video spectropolarimeter
- ITS-7D spectrometer
- KAP-350 topographic camera
- MKF-6MA multi-spectral camera (0.5-0.9  $\mu\text{m}$ , 10-15 m resolution)
- MKS-M2 multi-band spectrometer

Kristall Module:

- Priroda 5 multi-purpose high resolution (5 m) camera

Existing plans call for the launch in late 1995 of the Priroda (Nature) auxiliary module to augment substantially the Earth observation capabilities of the Mir space station complex. With a basic structure mass of 19.7 metric tons, a volume of more than 66 m<sup>3</sup>, a length of approximately 12 m (without solar panel deployment) and a maximum diameter of 4.35 m, Priroda is the most sophisticated and complex Earth observation spacecraft undertaken by the

Russian Federation (Figure 4.92). The overall mission objectives of the Priroda module are the:

- determination of the atmospheric-ocean system characteristics;
- measurements of the land local characteristics;
- measurement of optical characteristics of the atmosphere;
- investigation of the sea surface roughness state;
- comparison of radiation and reflection characteristics of the sea surface in the microwave range; and
- measurements of the concentrations of trace gases in the atmosphere."

The principal Earth observation instruments to be carried by the Priroda are described in Table 4.9. The Delta-2P and Ikar-N radiometers and the Travers synthetic aperture radar have been designed by the Moscow Energy Institute, while the Russian Academy of Sciences' Institute of Space Research is responsible for the Obzor spectrometer. The Moscow Energy Institute has also developed the 2.25-cm wavelength Greben radar altimeter which will provide precise altitude data with an accuracy of 0.1 m for correlation with the Earth observation systems. The MSU-E and MSU-SK multi-spectral scanners are being provided by

the Space Instrument Building NPO, and the Istok-1 spectrometer is a product of the Academy's Institute of Physics.

The module will be powered by a 35 m<sup>2</sup> array with a generating capacity of 4.2 kW but an average daily power availability of only 0.5-1.0 kW. Peak loads of up to 7 kW will be possible. Finally, the Centaur data acquisition system, similar to the Okean Condor system, will be operated for the collection of environmental information from various terrestrial sites. The Centaur system was created by the Moscow Energy Institute (References 717-719).

The other major module yet to be attached to the Mir space station is known as Spektr. Of similar size and mass as Priroda, Spektr will be used to conduct a wide assortment of studies, including "investigations of the surface-atmosphere system and studies of the Earth's natural resources." Specific Earth observations instruments earmarked for Spektr are the Oktava optical system developed by the USSR/Russian Academy of Sciences, the Kometa TsNPO, and the Kazan Optical-Mechanical Works for investigations of the surface-atmosphere system via the Pion-K, Lira, and the Buton devices; the Balkan 1 apparatus developed by the Siberian branch of the USSR/Russian Academy of Sciences for lower atmosphere measurements; the Faza and Feniks

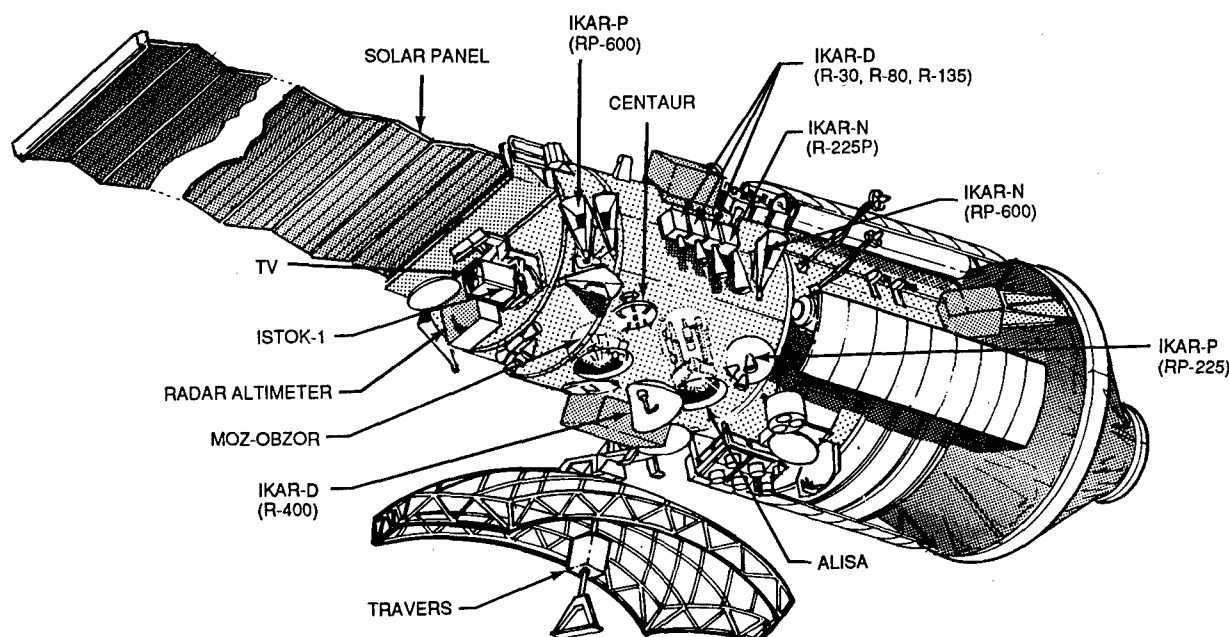


FIGURE 4.92 PRIRODA MODULE FOR THE MIR SPACE STATION.



TABLE 4.9 PLANNED PRIRODA MODULE EARTH OBSERVATION INSTRUMENTS.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS	GROUND SWATH	GROUND RESOLUTION
IKAR-D SCANNING RADIOMETER	4	0.3 cm 0.8 cm 1.35 cm 4.0 cm	400 km	5 km 8 km 15 km 30 km
IKAR-N STARING RADIOMETER	5	0.3 cm 0.8 cm 1.35 cm 2.25 cm 6.0 cm	60 km	60 km 60 km 60 km 60 km 60 km
IKAR-P PANORAMIC RADIOMETER	2	2.25 cm 6.0 cm	750 km	75 km 75 km
ISTOK-1 IR SPECTROMETER	64	4.0-16.0 $\mu\text{m}$	7 km	0.7 x 2.8 km
MOZ-OBZOR MULTI-SPECTRAL SPECTROMETER	17	0.415-1.03 $\mu\text{m}$	60 km	600 m
MSU-E MULTI-SPECTRAL SCANNER	3	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.8-0.9 $\mu\text{m}$	27 km	25 m 25 m 25 m
MSU-SK MULTI-SPECTRAL SCANNER	5	0.53-0.59 $\mu\text{m}$ 0.61-0.69 $\mu\text{m}$ 0.7-0.8 $\mu\text{m}$ 0.9-1.0 $\mu\text{m}$ 10.4-12.6 $\mu\text{m}$	350 km	120 m 120 m 120 m 120 m 400 m (?)
OZON-M SPECTROMETER	UNK	0.26-1.02 $\mu\text{m}$	--	1 km (in height)
TRAVERS SAR	2	9.2 cm 23.0 cm	80 km	100 m 100 m
ALISA AEROSOL LIDAR (FRANCE)	1	.532 $\mu\text{m}$	--	--

instruments produced by the Estonian Academy of Sciences and the Integral design office of the Leningrad State University for spectral analysis of the Earth's surface; and the Astra 2 sensor from the State Committee on Hydrometeorology to measure gas and ionization levels in the upper atmosphere. Modifications to Spektr in accordance with the Shuttle-Mir program may result in some of these instruments being deleted (Reference 720).

Numerous proposals have been made for both relatively simple and extremely sophisticated ecological monitoring systems which could be fielded near or after the turn of the century. In 1990 the Institute of Space Research suggested the EKOS program of relatively small LEO satellites with a maiden mis-

sion possible by 1996 (Reference 721). An international effort, managed by the USSR Academy of Sciences, evolved into the EKOS-A and EKOS-D projects. The former would utilize a Regatta-class satellite (Section 5.2.5) in a halo orbit 1.7 million km above the Earth and a Resurs-EKOS satellite in a 900-km, sun-synchronous orbit. The objectives of EKOS-A would be to understand the effects of solar activity, the ozone layer, atmospheric pollutants, large scale atmospheric eddies, and overall climate on the biosphere. EKOS-D would examine and forecast local natural resources and ecological processes with large spacecraft, including space stations.

The Lavochkin NPO has designed a variety of remote sensing spacecraft based on a new

3.5-metric-ton, 4-kW satellite bus named Freight which could be launched from the Baikonur Cosmodrome on converted SS-18 ICBM's. The two principal remote sensing versions of Freight (other variants can support technological, materials science, and biological science experiments) are EKOL and Ozone. The configuration of the 5.2-metric-ton EKOL (Figure 4.93) has varied with potential SAR (30-100 m resolutions) and multi-spectral (0.4-10.3  $\mu\text{m}$  with 5-10 m resolution) instruments. Ozone would carry a lidar (0.8 m diameter mirror) at altitudes of 600-900 km to study ozone concentrations as part of its 5-metric-ton mass. Another Lavochkin project called Monitor envisions a small, 600-kg spacecraft launched by a Kosmos booster for moderate resolution Earth observations in the 0.4-12.5  $\mu\text{m}$  band (Reference 722).

The Salyut Design Bureau of the Khrushchev State Space Scientific Production Center, with its long history of development of large spacecraft, proposed in 1991 an unmanned, free-flying space station named Tellura-EKO. Based on the current series of augmentation modules designed for the Mir space station, Tellura-EKO (Figure 4.94) would have a total

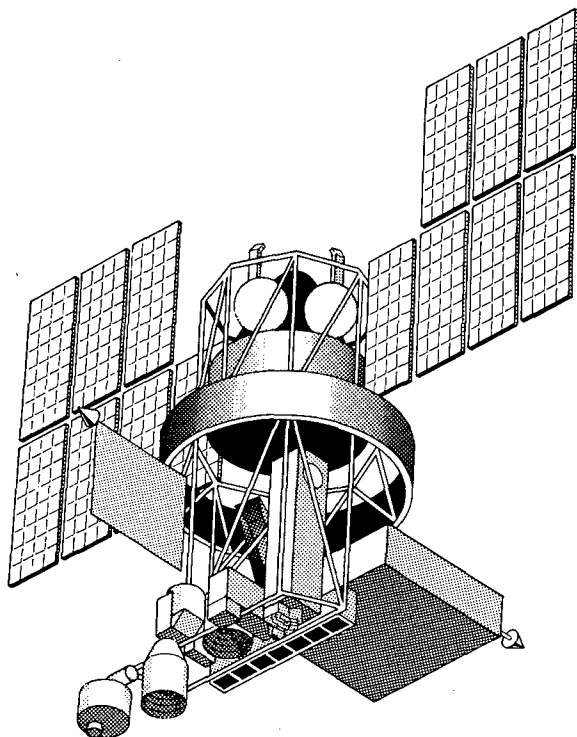


FIGURE 4.93 EKOL SATELLITE.

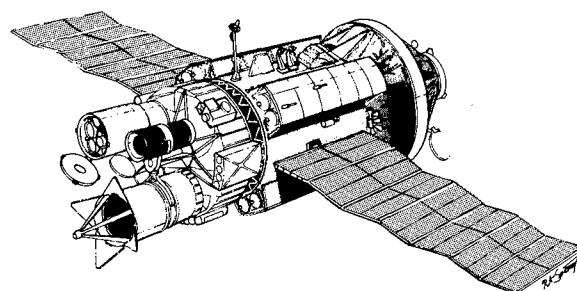


FIGURE 4.94 TELLURA-EKO SATELLITE.

mass of approximately 20 metric tons, half of which would be available for the remote sensing payload. With a basic maximum diameter of 4.4 m and a length of 12 m, the vehicle would use two large solar arrays to generate up to 5 kW of electrical power.

The Tellura-EKO program would consist of:

- Accommodation on its board and placing into orbit home and foreign made scientific and special purpose equipment, including:
  - a) unified multi-frequency lidar complex;
  - b) TV-complex;
  - c) radio and spectrometry complexes;
  - d) detachable container with synthetic substances (clouds) sources.
- Recording and transmitting to Earth hydrometeorological, geophysical and ecological information stipulated for by a potential partner, i.e.:
  - size, structure and concentration of atmospheric aerosol stratification layers, velocity and direction of their displacement;
  - atmospheric concentration of poisonous sulphurous, ammonia, and nitric gaseous combinations;
  - ozone concentration vertical distribution with 1 km altitude resolution in the range of 10 to 80 km;
  - wind altitude and spatial parameters measurement with 1 km resolution in the range of altitudes from 3-50 km;
  - cloud top altitude measurement with 10 to 100 m accuracy;
  - cloud cross-section with 300 to 1200 m spacing and fleecy clouds registering with 150 m altitude and 1-5 km horizontal accuracy;
  - tropospheric and stratospheric aerosol distribution with 300 to 2400 m altitude

- and 1000 to 1500 m horizontal spacing;
- atmospheric temperature and density in the altitude range 30 to 100 km with respective accuracy of 2 to 8° K and 2 to 4%;
- slight sodium, potassium, lithium, as well as potassium, magnesium and fermium ion and mixtures at the altitude of 80 to 100 km with 20 to 60% accuracy;
- ionosphere and magnetosphere condition, solar activity, etc.
- Processing the accumulated information and delivering it to the user in a generalized form - photographs, photomontage, positives, duplicate negatives, digital information, tape-recorded information through communication links, topical maps and charts, etc." (Reference 723).

The 1991 description of Tellura-EKO predicted a first flight as early as 1994 with Western participation. A development investment of 90 million dollars was estimated but operational costs for the period of 1995-1998 were predicted to be only 8 million dollars. The total lifetime of the spacecraft could be up to five years at an altitude of 400-450 km and inclinations of 52-72°.

Almost simultaneous with the Tellura-EKO proposal came the Salyut Design Bureau's concept of a slightly less sophisticated spacecraft known as Ecologia (Figure 4.95). With roughly the same physical characteristics (mass of 21 metric tons, payload of 8-9 metric tons, average power of 3 kW), Ecologia was designed to operate at altitudes of 350-450 km for 3-5 years. Orbital inclinations of 51°, 65°, or 73° are possible. The original Ecologia prospectus indicated that a launch by 1993 was possible, however, without foreign investment the program is unlikely to be fulfilled (Reference 724).

Meanwhile, RKK Energiya, relying on their experience with the Progress-M and Gamma spacecraft, have conceived a new, nearly 10-metric-ton, sun-synchronous satellite with a variety of Earth observation sensors, including a side-looking radar, a television camera, a vidiospectrometer, and a scanning radiometer (Figure 4.96) The scientific payload could reach a mass of 1.4 metric tons with an available power of 2 kW. From an operating altitude of 400-800 km, the spacecraft would be able to return data directly or via a relay satellite for a

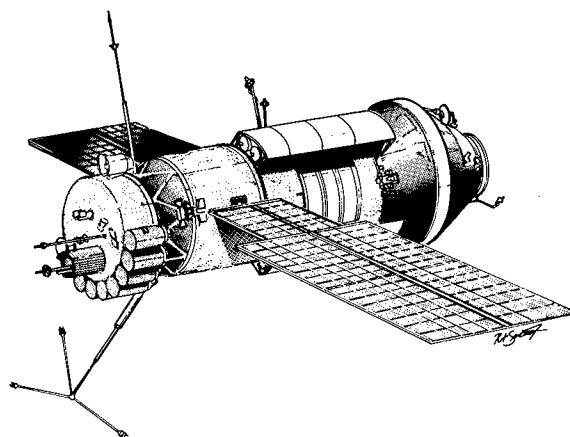


FIGURE 4.95 ECOLOGIA SATELLITE.

period of 3-5 years. If approved, launch by the Zenit booster would not come until 1996 or later.

Finally, the Arsenal Design Bureau has proposed converting its military ocean reconnaissance spacecraft bus (EORSAT) into a civil remote sensing platform. Called Obzor, the new spacecraft would feature a 4-channel model of the Travers SAR with a large antenna similar to the one proposed for Almaz 2. Developed by the Moscow Energy Institute, the radar would operate at wavelengths of 5.7, 9.2, 23.5, and 65 cm and would employ new processing and interpreting techniques created by the Institute for Space Geoinformation. The size and mass of Obzor would necessitate employing a Rus launch vehicle rather than the Tsyklon-2 used by EORSAT (Reference 725).

#### 4.3.12 South Korea

In August, 1992, South Korea's first satellite was launched as a piggyback payload on the Topex/Poseidon mission. The 50-kg microsat is known variously as Kitsat 1, Oscar 23, and Uribyol 1 (Our Star). Along with a communications payload, Kitsat 1 carried two CCD cameras for Earth photography in a 1,300 km by 1,400 km orbit inclined 66° to the equator. The principal national organizations participating in the program are the Korea Advanced Institute of Science and Technology and the Korea Research Institute of Standards and Science. The satellite was created with the help of the University of Surrey, England, which specializes in microsatellite technology. Kisat 2 was launched in a similar manner to its predecessor

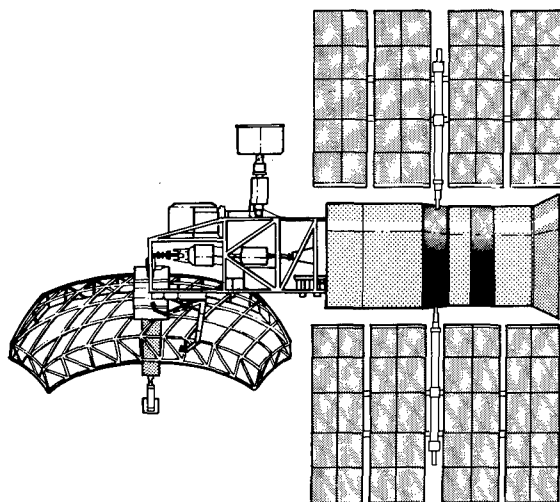


FIGURE 4.96 RKK ENERGIYA LEO EARTH OBSERVATION SATELLITE.

on 26 September 1993 and was inserted into an orbit of 795 km by 805 km at an inclination of 98.7°. Again, the small satellite carried two CCD imaging systems, one of which was of Korean design (References 726-729).

South Korea's next venture into Earth observation satellite systems will come with the 1998-1999 launch of the Korea Multipurpose Satellite (KOMSAT). The 400-kg satellite, which will be built by TRW, will tentatively carry a 10-m resolution CCD imaging system for Earth surveys at an altitude of 685 km (Reference 730).

#### 4.3.13 Ukraine

Although the National Space Agency of Ukraine was formed in March, 1992, and the country already had expertise in developing full satellite and launch vehicle systems, the country was slow in preparing for its first official national satellite. This situation should be remedied in 1995 with the launch of the Sich-1 spacecraft, aka Okean-O. Based on the oceanographic series of spacecraft developed by the Yuzhnoye Scientific Production Association under the USSR regime (Section 4.3.11), Sich-1 is reportedly the last of its kind and will be followed by more advanced Earth observation satellites (References 731-734).

Each Okean spacecraft has a mass of a little more than 1,900 kg, with a payload capacity of 550 kg and is launched from the Plesetsk Cosmodrome by the Tsyklon-3 booster, also made by Yuzhnoye NPO. The spacecraft bus is a three-segmented, vertically oriented cylinder, three meters tall with a base diameter of 1.4 m

and an upper diameter of 0.8 m. Okean's primary structure is pressurized and maintained at normal temperatures to protect the support system and payload electronics housed within. Two small, rotatable solar arrays (1.6 m wide and 2.0 m tall) provide a modest 110-270 W average daily power to the payload. Stabilization is partially provided by a gravity-gradient boom extended from the top of the satellite. At the bottom, four large panels (1.0 m wide and 2.9 m long), attached at 90° intervals, support a number of payload receivers and transmitters. A narrow, 11-m-long radar antenna is fixed to the base of one panel (Figure 4.97).

Okean spacecraft transmit data in realtime on 137.400 MHz using APT formats similar to that employed by Meteor satellites with a scan rate of 4 lines per second. Data is also stored and retransmitted on 466.5 MHz to the three principal data reception and processing centers at Moscow, Novosibirsk, and Khabarovsk. Table 4.10 indicates the typical set of instruments on board an Okean satellite, their characteristics, and the potential transmission modes. The APT images may be sent in one of four formats: (1) one low resolution scanner, (2) side-looking radar and microwave scanning radiometer, (3) side-looking radar alone, and (4) a combination of radar, microwave, and visible images. Figure 4.98 from the Kosmos 1500 Okean-OE depicts radar (left) and visible (right) images of the Middle East region. The original image size is 195 mm by 290 mm with a scanning density of 7.6 lines per mm and at least 12 gray level (References 735-740).

The major Okean payload is the real-aperture, side-looking RLS-BO radar operating with a vertically polarized 9.5 GHz frequency. This

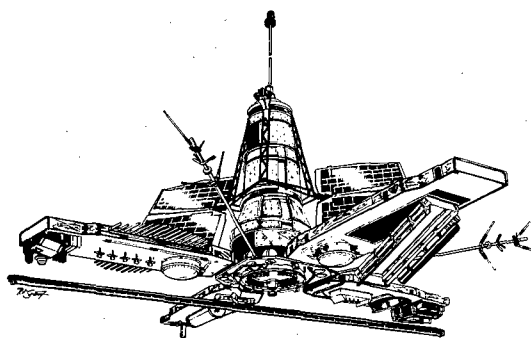


FIGURE 4.97 SICH-1 (OKEAN) SATELLITE.

TABLE 4.10 TYPICAL SICH-1 (OKEAN) INSTRUMENT SUITE.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS	GROUND SWATH, KM	GROUND RESOLUTION, KM	TRANSMISSION MODE
MULTI-SPECTRAL SCANNER (MSU-M)	4	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.7-0.8 $\mu\text{m}$ 0.8-1.1 $\mu\text{m}$	1930	1.0 x 1.7	DIRECT, STORE/DUMP
MULTI-SPECTRAL SCANNER (MSU-S)	2	0.5-0.7 $\mu\text{m}$ 0.7-0.9 $\mu\text{m}$	1380	0.35	STORE/DUMP
REAL APERTURE SIDE-LOOKING RADAR (RLS-BO)	1	3.15 cm	450	1.8 x 2.2	DIRECT, STORE/DUMP
SCANNING MICROWAVE RADIOMETER (RM-08)	1	0.8 cm (Horizontal Polarization)	550	15 x 15	DIRECT, STORE/DUMP
OPTICAL SPECTROMETER - EXPERIMENTAL (TRASSER)	2 x 50	0.4-0.8 $\mu\text{m}$	--	45	STORE/DUMP

instrument, developed by the Radio Engineering and Electronics Institute (IRE) in Kharkov, provides not only surface characteristics of land, sea, and ice but also near-surface wind speeds and sub-surface features. The last has



FIGURE 4.98 OKEAN DUAL VISIBLE AND RADAR IMAGE OF THE MIDDLE EAST.

proved to be exceptionally effective in determining ice thickness in the polar regions as an aid to naval navigation.

From its orbital altitude of 635 km by 665 km at an inclination of 82.5°, an Okean satellite employs both nadir-centered and off-nadir swaths. The MSU-M and MSU-S sweeps are centered about the sub-satellite point, but the RLS-BO and RM-08 swaths are displaced to the left of the ground track. The boresight of the MSU-M can be shifted up to 30° along the direction of the flight path. In part, due to power limitations, the MSU-M and RM-08 cannot be operated for more than 30 minutes at a time, and the RLS-BO is restricted to 10-minute sessions.

Okean satellites also serve as the central node in the Condor system which collects environmental data from small, remote stations on land, water, or ice. These stations, designated Condor-1, are interrogated by Okean satellites at 460.03 MHz and then transmit their data at 1553.4 MHz during a 4-12 second contact. Okean, also known as the Condor-2 node, then relays the data to special Condor-3 processing stations at 460.03 MHz. Okean satellites can interrogate Condor-1 stations within 800 km and can store up to 64 kbits of data for subsequent relay to a Condor-3 site.

Earlier designs for an Okean-M spacecraft, with dual side-looking radars and other improved Earth observation sensors, have apparently been shelved in favor of a second-generation system now known as the Sich-2

TABLE 4.11 PROJECTED SICH-2 INSTRUMENT SUITE.

INSTRUMENT	NUMBER OF SPECTRAL BANDS	BAND WAVELENGTHS	GROUND SWATH, KM	GROUND RESOLUTION, KM
MULTI-SPECTRAL SCANNER (MSU-M)	4	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.7-0.8 $\mu\text{m}$ 0.8-1.1 $\mu\text{m}$	1930	1.0 x 1.7
MULTI-SPECTRAL SCANNER (MSU-SK)	5	0.53-0.59 $\mu\text{m}$ 0.61-0.69 $\mu\text{m}$ 0.7-0.8 $\mu\text{m}$ 0.9-1.0 $\mu\text{m}$ 10.4-12.6 $\mu\text{m}$	600	.175 x .245 .175 x .245 .175 x .245 .175 x .245 .590 x .820
MULTI-SPECTRAL SCANNER (MSU-V)	8	0.45-0.52 $\mu\text{m}$ 0.52-0.62 $\mu\text{m}$ 0.62-0.74 $\mu\text{m}$ 0.76-0.9 $\mu\text{m}$ 0.9-1.1 $\mu\text{m}$ 1.55-1.75 $\mu\text{m}$ 2.1-2.35 $\mu\text{m}$ 10.0-12.0 $\mu\text{m}$	180	.050 x .050 .050 x .050 .050 x .050 .050 x .050 .050 x .050 .10 x .10 .25 x .25 .10 x .10
MULTI-SPECTRAL SCANNER (MSU-E)	3	0.5-0.6 $\mu\text{m}$ 0.6-0.7 $\mu\text{m}$ 0.8-0.9 $\mu\text{m}$	45 ( $\pm 300$ km off nadir)	.025 x .035
REAL APERTURE SIDE-LOOKING RADAR (RLS-BO D)	1	3.15 cm	2 x 700	1.5 x 2.0
OPTICAL SPECTROMETER (VIDEO)	2 x 6 (From 2 x 256)	0.4-0.8 $\mu\text{m}$	740	1
SCANNING MICROWAVE RADIOMETER (DELTA 2)	4	0.8 cm 1.35 cm 2.25 cm 4.3 cm (Horizontal, Vertical Polarization)	900	16 x 21 27 x 35 47 x 62 87 x 115

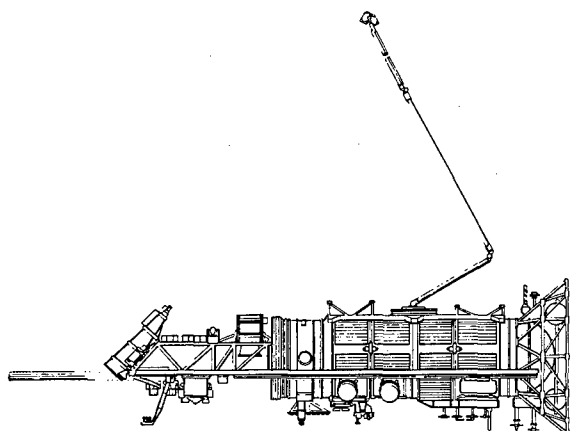


FIGURE 4.99 SICH-2 SATELLITE.

satellite (formerly known as Platform B) (Reference 741). SICH-2 will be launched by a Zenit-2 booster into a 650-km, sun-synchronous orbit. The overall dimensions of the horizontally oriented vehicle are 3.6 m in diameter and a length of 10.7 m, excluding the side-looking radar antenna (Figure 4.99). The spacecraft will have a 3-axis attitude control system with a pointing accuracy of 8 arc minutes.

The spacecraft bus will be a pressurized cylinder 1.9 m in diameter and 6.6 m long. A single solar array deployed above the spacecraft will deliver an average daily power of 800 W to the payload. The originally planned instrument suite (Table 4.11) will utilize both analog APT (137.4 MHz) and high capacity digital (8.2 GHz) data links. SICH-2 with a one-year

design life may also carry the Condor-2 data relay system.

#### **4.4 MATERIALS SCIENCE**

The microgravity conditions available in Earth orbit have given rise to an entirely new branch of materials science. Whether the objective is to grow high quality semi-conductor crystals, to prepare purer medicines via electrophoresis, or to develop practical techniques for welding, soldering, or metallic coatings, manned and unmanned satellites offer unique opportunities not only for pioneering experiments but also for commercial production. Although the slow development of this scientific discipline has not yet met many expectations, interest in space-based materials science investigations continues to grow in Europe and Asia.

To date in Eurasia only the Russian Federation and PRC have the capability to launch and to retrieve materials science payloads. In addition to supporting their own national programs, these materials science platforms are made available on a commercial basis to other nations. With the help of the US, ESA and Japan are expanding their materials science programs, while a joint German-Russian-Japanese venture is creating a new recoverable spacecraft designed specially for microgravity research.

##### **4.4.1 European Space Agency**

Under ESA's charter participation in microgravity research programs, which were formally established in 1982, is optional for member states. Significant activities did not begin until the flight of Spacelab 1 on the US STS in 1983. To date the majority of ESA's materials science programs remain linked to STS, including ESA's orbital free-flying EURECA satellite which is designed for deployment and retrieval by STS. In 1994 microgravity research emphasis was shifting toward parabolic aircraft flights and away from space missions. The recent elimination of the Columbus independent platform and the rescoping of the Hermes spaceplane program will limit future ESA experiments in this field until the International Space Station is operational. In the meantime, ESA astronauts have the opportunity to conduct materials science experiments on the Russian Mir space station (Reference 742).

Following the ESA Ministerial Meeting at The Hague in November, 1987, the long-term, 4-phase microgravity program was revised taking into account the effects of the Challenger accident of 1986. Phase 1 (1982-1985) had already been completed with the first flights of Spacelab. Phase 2 (1986-1992) and its extension included additional Spacelab missions and the first flight of EURECA. Phase 3 (1989-1997), termed the pre-Columbus phase, envisioned continued operations of Spacelab and EURECA while developing the Man-Tended Free-Flyer. Phase 4 (1998-2000) was called the Columbus Utilization Period, during which the volume and sophistication of materials research would be greatly expanded. In 1993 ESA's Microgravity Program Board approved a restructuring of the agency's microgravity activities into "two distinct financially independent elements: a basic European Microgravity Research Program (EMIR) and a program to develop microgravity experimental facilities for Space Station/ Columbus (MFC)" (References 743-744). Although the pace of the program has not met expectations, a strong commitment for materials science research remains within ESA.

Spacelab, in its many possible configurations, represents a major ESA development effort tailor-made for integration into the US STS program (Section 3.1). With a mass of up to 14.5 metric tons, Spacelab is actually a modular system which can be assembled in a variety of forms using a Pressurized Module (short or long) and payload pallets. The long Pressurized Module, in which crew-tended materials science experiments can be performed is approximately 4 m in diameter with a length of 7 m and a total mass in excess of 8 metric tons. The Pressurized Module is connected to the Orbiter crew cabin via a 1.3 m diameter tunnel. One to five 2.9 m long equipment pallets can also be part of a Spacelab configuration depending upon flight needs and the presence of a short or long Pressurized Module. A "typical" Spacelab mission includes a long Pressurized Module and one or two pallets. Principal contractors for Spacelab included Matra Marconi (France) for command and data management, Dornier (Germany) for environmental control and life support systems, AEG-Telefunken (Germany) for electrical power distribution, Aeritalia (Italy) for the Pressurized Module, Fokker (The Netherlands) for the airlock, and

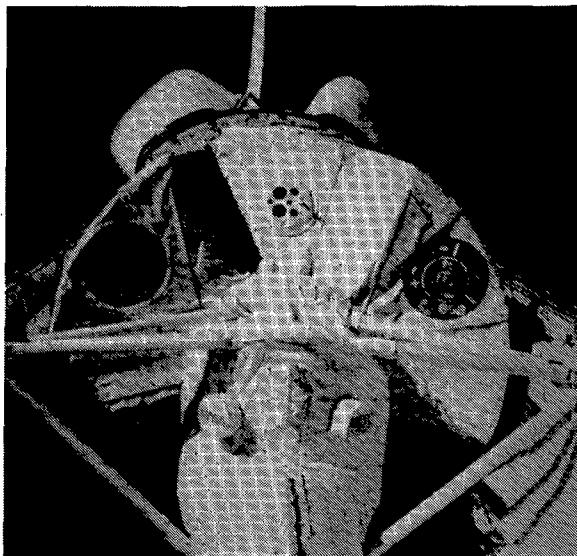


FIGURE 4.100 SPACELAB IN ORBIT.

British Aerospace (UK, now part of Matra Marconi) for the pallets (References 745-746). Together, France, Germany, Italy, and the UK contributed more than 85% of the funding for Spacelab.

Although Spacelab (Figure 4.100) has flown on numerous STS missions, only a few have supported major ESA materials science research: Spacelab 1 (1983), Spacelab D1 (1985), IML-1 [International Microgravity Laboratory] (1992), Spacelab D2 (1993), and IML-2 (1994). The STS-55 mission (April-May, 1993) carried the German-sponsored Spacelab D2 along with ESA's Advanced Fluid Physics facility. The following US Space Shuttle mission, STS-57 (June-July, 1993) not only retrieved ESA's EURECA satellite (below) but also supported protein crystallization experiments in the Spacelab module. The July, 1993 flight of IML-2 permitted a variety of ESA materials science devices to be operated, including the Bubble Drop and Particle Unit, the Critical-Point Facility, and the Advanced Protein Crystallization Facility (References 743, 747-749).

In 1982 ESA formally approved the development of a free-flying satellite dedicated to microgravity research during missions lasting six months or longer. The European Retrievable Carrier (EURECA) was finally launched 31 July 1992 on board the Atlantis Space Shuttle and deployed two days later. The 4.5 metric ton spacecraft with a 1 metric ton payload used its own propulsion system to maneuver into an operational orbit of approximately 500 km at an inclination of 28.5° (Figure 4.101). The two solar

arrays can generate up to 5 kW with 1 kW average power available to the payload (References 750-752).

The prime contractor for EURECA was MBB/ERNO of Germany, assisted by major subcontractors Matra Marconi, Fokker, Aeritalia, AEG, and SNIA/BPD. On its first flight EURECA was expected to achieve microgravity conditions of  $5 \times 10^{-7}$  g and carried five Microgravity Multi-User Facilities: Automatic Monoellipsoid Mirror Furnace (AMF), the Exobiology and Radiation Assembly (ERA), the Multi-Furnace Assembly (MFA), the Protein Crystallization Facility (PCF), and the Solution Growth Facility (SGF). Also on board were the High Precision Thermostat (HPT) and the Surface Forces Adhesion (SFA) materials science experiments. After a stay in Earth orbit of 11 months (2 months longer than originally planned), EURECA was successfully retrieved during the STS-57 mission and returned to Earth 1 July 1993. However, ESA budgetary constraints have cast doubt on whether EURECA will ever fly again (References 753-757).

Under the original Columbus program, a free-flying man-tended laboratory, based on the Freedom Space Station attached module, would have been flown with a major emphasis on microgravity research. Launched in the late 1990's by the Ariane 5 booster, the 18 metric ton laboratory was to be serviced by Hermes spaceplane crews once or twice each year.

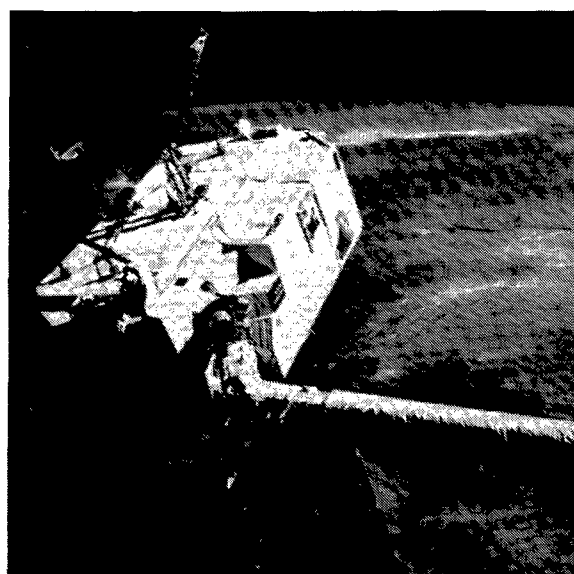


FIGURE 4.101 EURECA SATELLITE.



However, a redirection of the Columbus and Hermes programs in 1992 abandoned the free-flyer concept. Instead, emphasis will be placed on conducting materials science tasks on the International Space Station. Meanwhile, five material science experiments were performed during the Euromir 94 mission on the Mir space station in October, 1994 (Section 3.8).

#### 4.4.2 France

Although France has no current plans to operate dedicated microgravity research satellites, this nation has taken advantage of flight opportunities on US and Russian spacecraft to conduct materials science experiments. The 190-kg Mephisto electric furnace has flown twice on the US Space Shuttle (STS-52 in 1992 and STS-62 in 1994) to investigate directional solidification of metals. French materials science experiments have also flown on three Soviet/Russian Photon spacecraft. The 1990 Photon mission carried the CROCODILE (Croissance de Cristaux Organiques par Diffusion Liquide dans l'Espace) crystallization facility, while the 1994 flight involved the SEDEX (Synthese Enzymatique de Dextrane) enzyme synthesis experiment. In 1994 the Gezon installation on board a Photon spacecraft investigated the effects of magnetic fields on the crystallization process with the use of the Russian Zona-4M electric furnace. A second flight for CROCODILE is due in 1995, and the French firm Carrar is developing the Spacepack materials science experiment carrier for future Photon missions (References 758-761).

The CASIMIR experiment to study the growth of zeolites with a French furnace was conducted on the Resurs-F 9 vehicle in 1990. Two major materials science experiments were performed on the Mir space station in 1992 during the French Antares mission: Alice to study the transport and phase change phenomena in the neighborhood of critical points and Supra-conducteur to investigate the crystallization of a high critical temperature superconductor under zero-g conditions. A separate experiment studied the effects of heavy ions on electronic components in the space station. On the second International Microgravity Laboratory mission, a French electrophoresis apparatus was tested under the RAMSES (Applied Research on Separation Methods Using Space Electrophoresis) program. (References 762-763).

#### 4.4.3 Germany

For many years several German organizations, e.g., Intospace GmbH, Kayser-Threde GmbH, DASA, OHB-System GmbH, and DLR's Microgravity User Support Center, have been involved in numerous European microgravity experiments on such foreign orbital platforms as EURECA, FSW-1, Mir, Photon, Resurs-F, and Spacelab. The German mission to the Mir space station in 1992, the 1993 flight of Spacelab D2 on STS-55, and participation in IML-2 in 1994 on STS-65 represent the latest man-tended materials research efforts undertaken. Spacelab D2, in particular, hosted six furnaces, including the Material Sciences Experiment Double-rack for Experiment Modules and Apparatus (MEDEA) and the Material Sciences Laboratory. On IML-2 DARA sponsored the Quasi-Steady Acceleration Measurement experiment to monitor microgravity levels for various types of studies (References 749, 764-765).

In late 1992 the German national space agency agreed to develop with Japan and the Russian Federation a small, recoverable capsule for short-duration, low-altitude orbital missions. Named EXPRESS (Experimental Re-entry Space System), the 765-kg spacecraft (including an initial payload of nearly 130 kg) was to be launched by the last Japanese M-3SII booster from Kagoshima in the Summer of 1994. However, program difficulties prevented the mission from meeting the narrow Japanese launch window, and the flight was delayed until early 1995. Based in part on a Russian re-entry vehicle, the EXPRESS spacecraft consists of two basic components: a 400-kg recovery capsule and a 365-kg service module. The maximum flight time is one week with a re-entry g-load of up to 10 g's. The spacecraft has an overall length of 2 m and a maximum diameter of 1.4 m. If the first flight, which carried two German electric furnaces, was successful, plans called for additional missions by a to-be-determined small launch vehicle (References 766-774).

#### 4.4.4 Italy

In concert with its goal to develop the Vega launch vehicle, Italy is investigating potential payloads for the modest capacity booster. One of the leading concepts for a long-term program is the CARINA (Capsula di Rientro Non Abitata)

microgravity spacecraft. With a total mass of 450-500 kg, CARINA could carry a materials science payload of up to 160 kg into a 300-km, low-inclination orbit for operations of up to five days. Development Phase B activities were completed in 1994, permitting a maiden flight in the 1997-1998 time frame.

Current designs call for a spacecraft with a diameter of 1.2 m and a height of 1.7 m at launch, including the 1.0 m diameter, 1.2 m tall reentry capsule. The payload volume would be restricted to 0.3 m<sup>3</sup>, and power would be supplied from lithium batteries. Launches would be conducted from the San Marco platform in the Indian Ocean with water recoveries nearby. Alternatively, small foreign launch vehicles, e.g., the US Pegasus, could be employed (References 775-776).

#### 4.4.5 Japan

As indicated in Section 4.4.3 above, Japan will play a vital role in the EXPRESS microgravity program underway with Germany by providing the necessary launch services with its M-3SII booster. If the EXPRESS program is successful, the M-3SII could be replaced by the forthcoming M-5 or J-I boosters later in the decade.

Until 1992, Japan's opportunities for microgravity research were largely restricted to small sounding rocket flights, principally with the TR-IA. By the end of 1994 three flights of the TR-IA had been conducted (September, 1991; August, 1992; and September, 1993) specifically to prepare experiments for JEM on the International Space Station. However, interest in orbital materials research is growing rapidly, and a late start in this field may be overcome through a variety of programs slated for the remainder of this decade (Reference 777).

The flight of Spacelab J in September, 1992, included 24 materials science experiments as part of the FMPT (First Materials Processing Test) program. Specific equipment tested during Spacelab J by astronaut Mamoru Mohri and his American colleagues included the Acoustic Levitation Furnace (ALF), the Continuous Heating Furnace (CHF), the Crystal Growth Experiment Facility (CGF), the Gradient Heating Furnace (GHF), the Image Furnace (IMF), the Large Isothermal Furnace (LIF), the Liquid Drop Experiment Facility (LDF), the Gas Evaporation Experiment Facility (GEF), the Organic Crystal Growth Experiment (OCF), the Bubble

Behavior Experiment Unit (BBU), the Free Flow Electrophoresis Unit (FFEU), and the Marangoni Convection Experiment Unit (MCU). The LIF was reflown on IML-2 in July, 1994, to study the effects of microgravity on the microstructure and strength of ordered Titanium-Aluminum intermetallic alloys (References 778-780). Japan may sponsor additional experiments on a STS SpaceLab mission in 1996 (Reference 781).

The first domestic microgravity spacecraft is now scheduled for launch by the H-II booster in early 1995. Called the Space Flyer Unit (SFU), the reusable satellite is analogous to ESA's EURECA, i.e., SFU will be operated in LEO for 6-9 months conducting a variety of materials processing experiments before it is retrieved and returned to Earth by a US Space Shuttle. Also like EURECA, SFU will possess an initial mass of approximately four metric tons, including one metric ton of payload.

Mitsubishi is the prime contractor for SFU, which is being funded by the Ministry of International Trade and Industry through ISAS and NASDA in cooperation with the newly established Institute for Free Flyer Unmanned Space Experiments (USEF).

SFU consists primarily of an octagonal bus (4.9 m diameter, 3.0 m tall) and two large solar arrays (2.4 m by 9.6 m each) with a capacity of 2.7 kW. The solar arrays are retractable and will be stowed and redeployed several times during the mission as warranted by special experiments. The spacecraft will utilize a 3-axis stabilization system and will be equipped with a propulsion unit capable of maneuvering the vehicle to an operating altitude of nearly 500 km and returning to a lower retrieval altitude for STS (References 782-783).

The objectives for SFU are actually multipurpose to include materials science, life science, astrophysics, and space technology experiments. The platform will also serve to test equipment slated for use on JEM being built for the International Space Station. Three USEF materials science experiments are manifested for the first SFU mission: a gradient heating furnace (1,250° C capacity), an isothermal heating furnace (1,200° C capacity), and a mirror heating furnace (1,380° C capacity). ISAS will also sponsor the Material Experiment under Microgravity (MEX) to study the homogeneity of crystals grown in space. Meanwhile, NASDA will conduct material exposure experiments and

precisely measure the levels of microgravity present on SFU. The frequency of SFU missions will, in part, be determined by the US STS schedule.

Still in the concept development phase are two proposed spaceplanes with primary or secondary microgravity research objectives. ISAS is studying a Highly Maneuverable Experiment Space (HIMES) vehicle which initially would be limited to sub-orbital missions of approximately 30 minutes in duration. In its current design, HIMES is a 14-metric ton class spaceplane with a wing span of less than 10 m and a length of nearly 14 m.

Concurrently, NASDA continues to refine the design and objectives of the H-II Orbiting Plane (HOPE). Since its beginning in 1987, the HOPE program, which was originally linked to servicing the International Freedom Space Station, has been beset by budgeting and political difficulties. Delays and the growing costs in the H-II development program have affected government commitments to the HOPE project (References 784-788). Both 10-metric-ton and 20-metric-ton versions of HOPE have been proposed in manned and unmanned modes of operation (Section 2.6). If eventually deployed about the turn of the century, a 10-metric-ton, unmanned HOPE could become a major element in Japan's materials science program.

A nearer term option for man-tended microgravity research will be on board JEM, which is scheduled for launch in about 2000. This space station module is described in more detail in Section 3.4. At the present, JEM is being designed to support a wide variety of scientific and technology programs, including materials science investigations. Although the majority of such experiments will probably be conducted in the Pressurized Module (PM), the unique concept of replaceable Experiment Logistics Modules (ELMs) may also benefit microgravity research.

#### **4.4.6 People's Republic of China**

As noted previously, since 1987 the PRC has utilized its FSW Earth observation recoverable capsule for both small materials science and life science experiments (Reference 321). The FSW-2 spacecraft which was first introduced in 1992 is also being offered to support microgravity research and with its greater capacity will probably succeed the FSW-1 as the principal carrier of such equipment. By the

end of 1994, six FSW missions had carried domestic materials science experiments (References 789-791). The PRC has no announced plans for developing a larger, dedicated microgravity satellite, although a second generation, multi-purpose recoverable vehicle is under consideration.

Overall technical details of the FSW-1 and FSW-2 are provided in Section 4.3.9. Specific microgravity experiment limitations for the FSW-1 are 20 kg recoverable for piggyback payloads and 150 kg recoverable/150 kg non-recoverable for a dedicated mission. Similarly, the FSW-2 offers a 300 kg recoverable payload capacity in addition to another non-recoverable 400-500 kg. Maximum flight time is approximately eight days for FSW-1 and 15 days for FSW-2.

Two drawbacks of the current FSW-1 design are the high re-entry loads (up to 11 g's) and the moderate landing velocity (13-14 m/s). The European COSIMA payload flown in 1988 experienced fractures of a significant portion of the crystals grown in space, apparently due to harsh reentry and landing conditions. The FSW-2 will feature less stressing impact loads. On-orbit microgravity conditions are on the order of  $10^{-4}$  -  $10^{-5}$  g.

The domestic Chinese materials science research program appears to be still in its infancy. The first acknowledged payload for national interests was flown on FSW-0 9 (August, 1987). A general description of the Chinese experiments referred to smelting and recrystallization of alloys and semiconductor materials. Specifically, the Lanzhou Physics Institute is said to have performed work with yttrium-barium-copper superconductor samples. The FSW-1 1 mission the following month (September, 1987) also carried crystal growth experiments. Similar experiments were conducted on the 4th and 5th FSW-1 missions (1992 and 1993) and on both the FSW-2 flights (1992 and 1994).

#### **4.4.7 Russian Federation**

The materials science program in the USSR/CIS dates back to the first electron-beam welding experiments conducted on board Soyuz 6 in 1969. However, the experimental and pilot production activities have been underway in earnest since the launching of the Salyut 5 space station in 1976. Today, the Mir space station is the focal point of such operations with a

wide assortment of electric furnaces and other devices and with the added benefit of crew participation. One of the primary objectives of the Kristall module, attached to Mir in 1990, was to support microgravity experiments.

Despite the fact that microgravity conditions are typically 10-100 times worse on a manned versus an unmanned spacecraft, man-tended experiments on Soviet-built space stations, some lasting more than a week, proved to be quite successful. The other principal drawback of materials science research on Mir - the extremely limited capability of returning samples to Earth - was reduced in late November, 1990, when the Progress M recoverable capsule was successfully tested for the first time. This system is now used approximately twice each year, returning up to 150 kg of cargo (including the product of materials science research) per mission.

Whereas specific details of Mir operations are covered in Section 3.6, a list of major materials science devices delivered to the station are included here for completeness. In 1987 three electric furnaces were delivered to Mir: Korund-1M, Kristallizator, and Mirror-Beam. These were augmented or superseded in 1990 by the five new furnaces installed on the Kristall module: Krater V, Kristallizator, Optizon, Zona 2, and Zona 3. Other Mir materials science devices have been used for electrophoresis (Aynur-Kristall, EFU Robot, Ruchey, and Svetlana), protein crystallization (Aynur-Mir), and miscellaneous experiments (Biostoykost, Svetoblok, and Yantar). Most materials science experiments are of Russian origin, but some are created by Ukrainian specialists.

Beginning in 1985 the USSR/CIS conducted annual unmanned space missions dedicated to materials science research. The Photon spacecraft used for these flights is a derivative of the 1960's era Vostok/Voskhod manned spacecraft and the Zenit military reconnaissance satellites and is very similar to the currently operational Bion and Resurs-F satellites. Prototype Photon satellites were launched during 1985-1987 as Kosmos 1645, Kosmos 1744, and Kosmos 1841. Since 1988, the spacecraft have been officially designated as Photon.

The 6,200-kg spacecraft is 6.2 m in length with a maximum diameter of 2.5 m and is divided into three major sections: The service/retro module, the payload capsule, and an

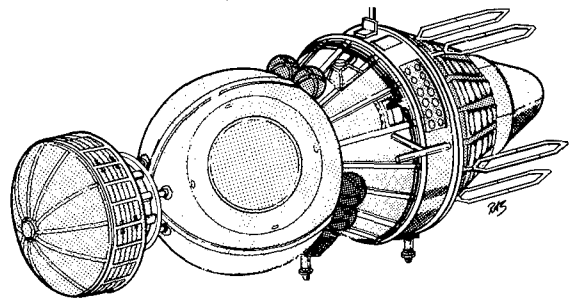


FIGURE 4.102 PHOTON SATELLITE.

equipment block (Figure 4.102). The 2.3-m diameter recoverable capsule can handle a payload of up to 700 kg and a volume of 4.7 m<sup>3</sup>. Electrical power is supplied entirely by storage batteries with 400 W average per day allocated to the payload (up to 700 W for 90 minutes each day). Mission durations for the eight Photon flights to the end of 1992 were 13-16 days (References 792-795).

To minimize perturbation forces, thereby maximizing microgravity conditions (as low as 10<sup>-5</sup> g), Photon spacecraft are placed in a mildly eccentric orbit at 62.8° inclination and are not maneuvered during the mission. The initial orbits for Photon 4 (4-20 October 1991) and Photon 5 (8-24 October 1992) were 215 km by 397 km and 221 km by 359 km, respectively. Prior to 1991 the annual Photon missions had always been launched in April or May. Launches are performed by the Soyuz booster from Plesetsk, and recoveries are made in Kazakhstan in the primary manned recovery region northeast of the Baikonur Cosmodrome.

The year 1993 marked the first time that a Photon mission was not undertaken in the course of the eight-year program. However, in 1994 Photon 6 was launched into an orbit of 221 km by 364 km on 14 June. In addition to Russian materials science experiments, Photon 6 carried out the French Gezon experiment using the Russian Zona-4M electric furnace. (Photon spacecraft have also flown the Zona 1, Zona 4, Splav 2, and Konstanta 2 electric furnaces as well as the Kashtan electrophoresis unit.) Photon 6, which also carried the European Biopan life sciences experiments, was successfully recovered on the 15th day (Reference 788). Two more Photon missions were scheduled for 1995, while a 1996 Photon

spacecraft will carry an experimental German reentry capsule named MIRKA. The French firm Carra is developing a new interface module for Photon called Spacepack, which will facilitate the integration of foreign microgravity experiments on Russian spacecraft like Photon (References 789, 796-797).

When Soviet officials decided to make the Photon spacecraft available to foreign commercial users, the similar Resurs-F1 Earth observation spacecraft was also offered for payloads of 15-30 kg. Working through the Kayser-Threde firm (Figure 4.103), several European sponsors have taken advantage of these more frequent flight opportunities: COSIMA 2 (Crystallization of Organic Substances in Microgravity for Application) on Resurs-F 5 (September, 1989), COSIMA 3 on Resurs-F 6 (May, 1990), and CASIMIR (Catalyst Studies for Industry through Microgravity Research) on Resurs-F 9 (September, 1990). Although mission durations can be increased to 25 days as compared to the 16-day flights of Photon, Resurs-F1 spacecraft are subject to attitude control adjustments and orbital maneuvers which may have a deleterious effect on microgravity experiments. Despite contracts for future microgravity experiments, none of the three Resurs-F missions of 1993-1994 carried such secondary payloads (Reference 798).



FIGURE 4.103 INSTALLING MICROGRAVITY EXPERIMENTS IN RESURS-F1 CAPSULE.

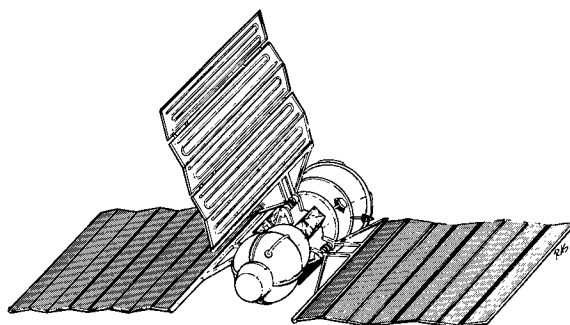


FIGURE 4.104 NIKA-T SATELLITE.

By the late 1990's the Photon Design Bureau anticipates testing a much more capable microgravity spacecraft as a follow-on to the successful Photon program. Designated NIKA-T (Scientific Research Spacecraft - Technological), the new vehicle will retain the spherical reentry capsule of Photon but will possess significantly improved support systems. The 9 metric ton NIKA-T will be capable of returning payloads of up to 1,200 kg after missions of 3-4 months. Early NIKA-T concepts envisioned a maximum spacecraft diameter of 2.7 m and a length of 9.3 m, but more recent diagrams suggest that the length has been reduced slightly. Two solar arrays will generate 6 kW of which 4.5 kW will be available for the microgravity payload (Figure 4.104). A third array is part of the thermal control system's heat rejection loop (References 793-795, 799).

NIKA-T will be launched by the Zenit launch vehicle into sun-synchronous orbits of 300-500 km at inclinations of 96-98°. To protect the fragile materials sciences samples, the landing velocity of the capsule will be reduced to only 5 m/s. At least two new materials science instruments are being developed for NIKA-T: the Zona 8 and the Konstanta 4 furnaces. The former will be capable of accepting sample cartridges of 40 mm diameter and 200 mm length, whereas the latter will possess a 85 mm diameter and 400 mm length capacity.

In 1990 the Lavochkin NPO announced plans to enter the microgravity services market with its own spacecraft, generally referred to as Lavochkin or Mercury. The original prospectus indicated a spacecraft mass of 5,600 kg and a payload mass of 500 kg. The descent module which was conical in shape had a mass of 2,900 kg. Electrical power was to be supplied by two solar panels with a 4.5 kW capacity. Mission durations of up to two years in orbits of 500 km and 97.7° inclinations were anticipated by 1993-

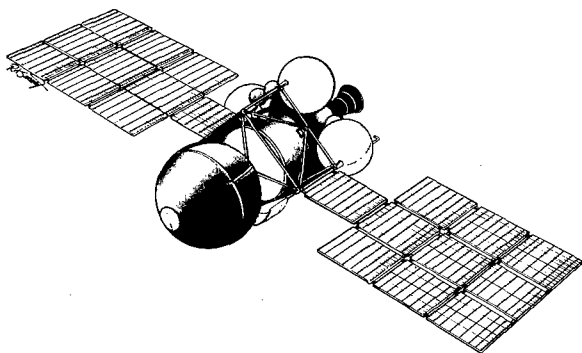


FIGURE 4.105 TEKOS SATELLITE.

94 with the aid of a modified RS-20 ICBM launch vehicle (References 800-802).

By 1991 the project had matured to include a new spacecraft design and a host of available materials science equipment. The current design calls for a spacecraft, called Lavochkin or Tekos, with a mass of 5,500 kg with a spherical 2.2 m diameter reentry capsule (based on the Venera reentry module) of 2 metric tons and a payload mass of 900 kg and volume of 4-4.5 m<sup>3</sup> (Figure 4.105). Solar-generated electrical power capacity will remain at 4.5 kW. Also unchanged was a goal of flight duration up to two years in a 500-km, 98°-orbit, launched by a modified RS-20. The maiden flight of the spacecraft was set for 1994, but delays of two or more years are anticipated. Expected microgravity conditions were 10<sup>-4</sup>-10<sup>-5</sup> g (References 803-806).

To sweeten the commercial package, Lavochkin NPO has teamed with specialists in the Russian materials science community to provide specific semiconductor and pharmaceutical microgravity devices for Tekos. Three electrophoresis instruments are being prepared (Potok, Meduza, and Shtamm) along with the Biocryst facility for the production of biocrystals. The Krater-AG furnace will have the capacity of handling sample cartridges 76 mm in diameter and 200 mm in length at temperatures of up to 1,270° C and total operations of 5,000 hours. Lavochkin NPO has estimated that 100 kg of gallium arsenide and 20 kg of other semiconductor materials could be produced on a single mission.

Not to be outdone by its longtime competitors (Photon Design Bureau and Lavochkin NPO), the Salyut Design Bureau of Proton launch vehicle and Mir space station fame pro-

posed about 1991 no less than four new concepts for materials science research with spacecraft of 1.2 metric tons to more than 100 metric tons. However, to date none of these designs appear to have secured project funding.

At the least ambitious end of the spectrum is the Space Biotechnological Complex, "intended for experimental production of exclusively pure biologically active substances possessing unique properties (unthought of gaining in the terrestrial conditions) and its manufacturing process improvement" (Reference 807). The 1,200-kg spacecraft (Figure 4.106) measures only 1.50 m in height and 1.45 m in diameter at the base. The core of the spacecraft is a recoverable module, similar to that introduced with Progress M spacecraft in 1990, surrounded by electrical and thermal control systems. Total recoverable payload mass is 100 kg with a diameter of 53 cm and a length of 100 cm. Designed for launch by a "light-weight launch vehicle," possibly the RS-18-derived Rokot (also created by the Salyut Design Bureau), the Space Biotechnological Complex may remain in its reference 400-km, 65°-inclination orbit for only five hours. A 1991 description of the project indicated that operations could start in 1993, although no serious effort was apparently underway by the end of 1994.

The second materials science spacecraft innovation being offered by the Salyut Design Bureau is called *Technologiya* and is based on a new spacecraft bus called the Unified Space

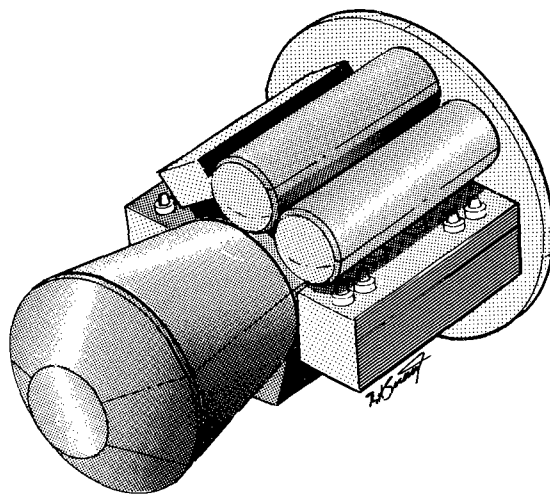


FIGURE 4.106 SPACE BIOTECHNOLOGICAL COMPLEX.

Platform (USP). The USP is designed to handle payloads of up to 10 metric tons with stowed dimensions of 4.1 m diameter and 6.7 m length. The USP will supply electrical power up to 12 kW, attitude control with a precision of  $10'$  to  $1^\circ$ , orbital maneuver capability, and other support functions. Mission durations of as long as five years are possible in orbits up to 500 km with inclinations of  $51.6^\circ$ ,  $65^\circ$ , or  $72^\circ$ . Launches would be provided by the Proton within 3-4 years of contract agreement (Reference 808).

Under the Technologiya program, the Salyut Design Bureau has already designed a customized microgravity payload unit for the USP (Figure 4.107). The 20 metric ton vehicle will be capable of carrying 4-5 metric tons of processing equipment for the manufacture of semiconductor materials, optical glasses, and biological preparations in a volume of up to  $30 \text{ m}^3$ . A maximum mission duration of three years at a 400-450 km altitude is possible. Products and processing equipment will be returned to Earth in a large recoverable module (Reference 809).

The third Salyut Design Bureau proposal is based on a derivative of the class of spacecraft which serve as the heavy add-on modules for the Mir space station, e.g., Kvant 2 and Kristall. Named the Biotechnologiya Space Vehicle, this proposed materials science spacecraft (Figure 4.108) has a launch mass of 21 metric tons of

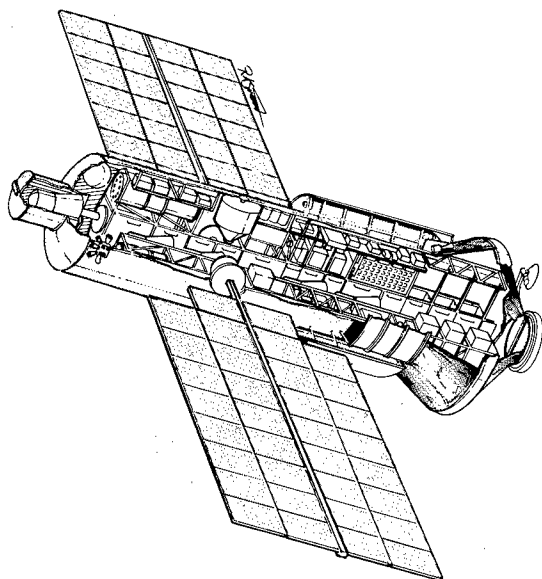


FIGURE 4.107 TECHNOLOGIYA SATELLITE.

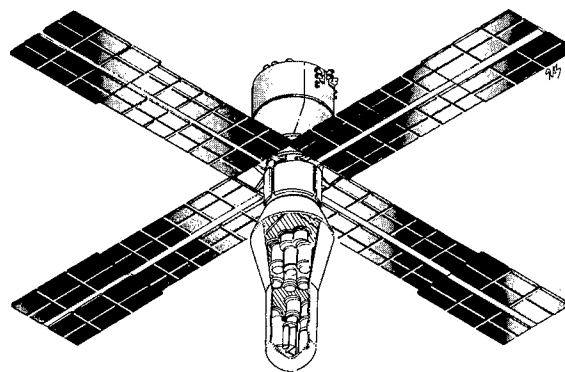


FIGURE 4.108 BIOTECHNOLOGIYA SATELLITE.

which 8-9 metric tons represent the payload. The maximum diameter is 4.3 m and the length is approximately 12 m. Two solar arrays generate up to 3 kW average power and 10 kW for peak loads. Microgravity conditions of  $10^{-4} \text{ g}$  are possible for year-long missions at altitudes of 350-450 km (References 810-811).

A unique aspect of the Biotechnologiya Space Vehicle is its ability to return materials in small recoverable modules periodically throughout the mission. Ballistic capsules (5 or more) with a capacity of 120 kg and a volume of 120 liters are loaded separately, then ejected from the main spacecraft for the return to Earth. Since the basic spacecraft systems have already been developed and tested in space, the preparation period for this specialized vehicle may be only 2-3 years.

In support of the first Energiya mission in 1987, the Salyut Design Bureau constructed a 100-ton class spacecraft called Polyus. Although the vehicle never reached orbit due to an attitude control problem, its designers have expanded upon the original concept to propose the heavy Space Processing Module (SPM), also known as the Engineering Production Module (TMP) (References 812-814). With a 102 metric ton launch mass, the SPM possesses an on-station (350-400 km,  $51.6^\circ$  inclination) mass of a mere 88 metric tons. In typical Russian style, the Salyut Design Bureau engineers adapted well-known hardware to create the SPM. The heart of the facility (the Laboratory Compartment), where the materials processing equipment is installed, is based on the main

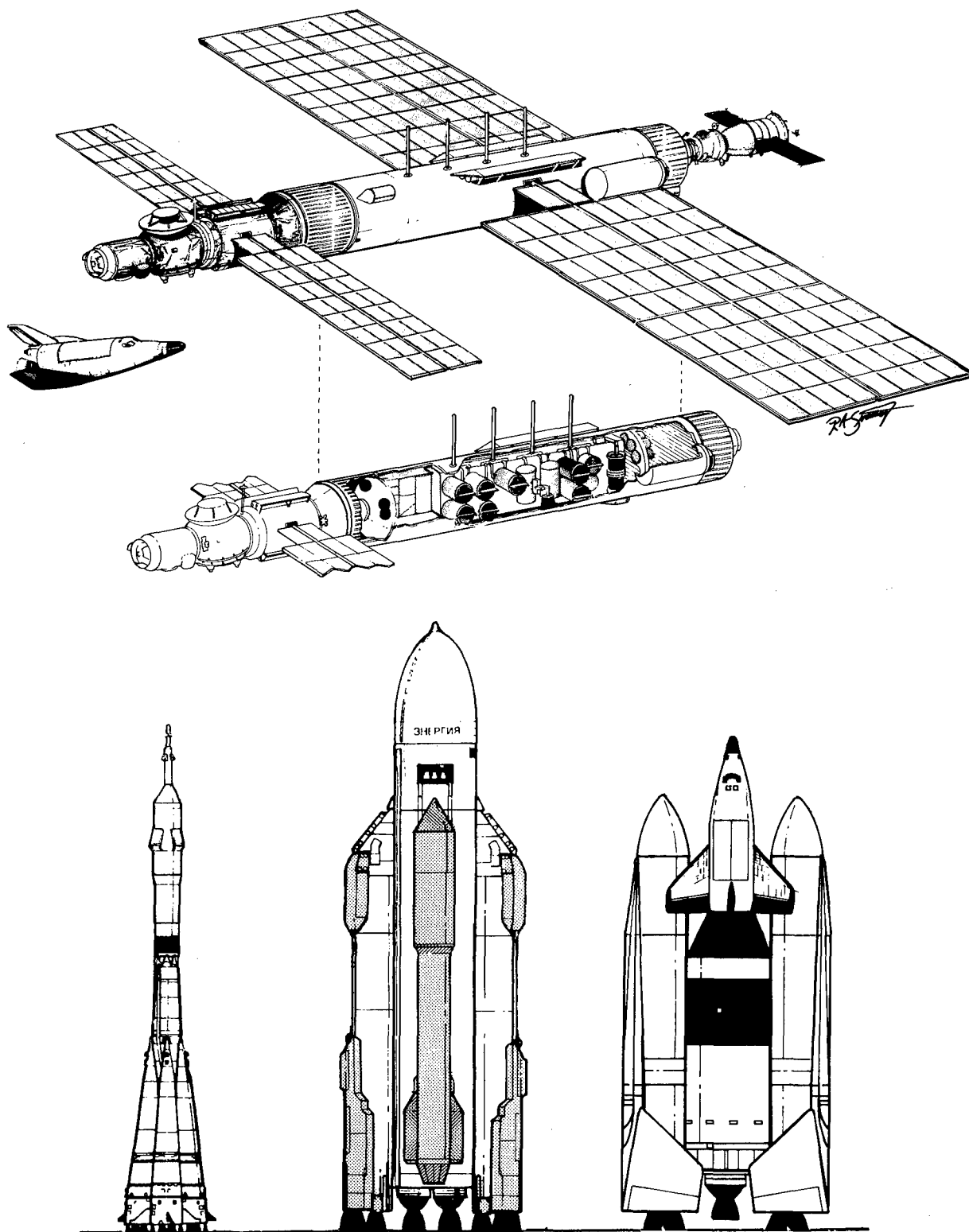


FIGURE 4.109 THE PROPOSED SPACE PROCESSING MODULE INFRASTRUCTURE, INCLUDING SOYUZ TM AND MAKH SPACEPLANE LOGISTICS VEHICLES.



core cylinder of the Proton launch vehicle's first stage. Above it is a heavy Kosmos module (the Instrument-Cargo Compartment) of the Kvant 2, Kristall, or Biotechnologiya class.

In orbit the SPM is approximately 35 m long with a main diameter of just over 4 m (Figure 4.109). In addition to the two sizable solar arrays extending from the Instrument-Cargo Compartment, the SPM has two very large arrays attached to the Laboratory Compartment - total span = 60.4 m. Together, they can produce more than 60 kW for a mission exceeding five years. Total payload mass of up to 25 metric tons is possible with microgravity conditions of  $10^{-5}$  -  $10^{-6}$  g.

Expanding upon the idea of multiple return capsules proposed for the Biotechnologiya Space Vehicle, the SPM designers have included a similar capability using 361 kg ballistic capsules with a payload mass of 141 kg and a payload volume of 92.5 liters. Robotics are used to remove a ballistic capsule from storage, load it, and then transfer it to a small air-lock for ejection. This operation cycle would occur every 1-3 months. Nine types of processing units have been proposed for the SPM for a total of

45 individual installations for an annual production capacity of more than one metric ton per year.

A novel element of the SPM program is the option for man-tended operations. Docking ports at both the aft and forward end of the SPM would be compatible with a Soyuz TM spacecraft or the proposed MAKS spaceplane. The latter could be launched either by the Energiya-M launch vehicle or from an air-based platform like the An-225. A maintenance or resupply crew could spend up to 10 days on the SPM unloading supply ships and repairing equipment. Unmanned resupply missions using Progress M or heavy Kosmos spacecraft are also envisioned. The advent of MAKS would also increase the opportunities (and therefore mass) for returning processed materials to Earth. Complete design of the SPM will require two years, followed by four years of building and testing the flight module before launch. However, with the demise of the Energiya and Energiya-M programs and Russia's participation in the International Space Station, the SPM concept is unlikely to be developed further.



#### References - Section 4

1. "Telecommunications: The OTS Legacy", Spaceflight, January 1989, p. 22-23.
2. "Marecs Satellite Monitoring Ukranian Radiation Levels", Space News, 1-7 August 1994, p. 12.
3. "ESA and Telecommunications", All About the European Space Agency, ESA, August 1992.
4. European Space—On Course for the 21st Century, ESA, BR-39, 1987.
5. "The Telecommunications Programme", ESA f-05, March 1989.
6. D. Smith, "Olympus, A Giant Amongst Satellites", Spaceflight, November 1989, p. 386-387.
7. Europe in Space, ESA, January 1983.
8. ESA Annual Report 1991, ESA, 1992.
9. A. Lawler, "Olympus Spins Out of Control The Night of Meteor Shower", Space News, 23-29 August 1993, p. 11.
10. "ESA Kills Olympus", Aviation Week and Space Technology, 30 August 1993, p. 22.
11. "Olympus Mission Ends", Spaceflight, November 1993, p. 389.
12. ESA Annual Report 1993, ESA, 1994.
13. ESA Annual Report 1994, ESA, 1995.
14. "Alenia Nets Artemis Work in Milestone ESA Contract", Space News, 11-17 October 1993, p. 13.
15. "Lasers in Space", Spaceflight, January 1994, p. 35.
16. "Optical Inter-Orbit Communications", Spaceflight, April 1995, pp. 116-117.
17. "Laser Ground Station", Spaceflight, June 1994, p. 183.
18. P.B. de Selding, "Artemis Schedule Slip May Be Costly", Space News, 3-9 January 1994, pp. 1, 20.
19. P.B. de Selding, "Massive Overrun Looms for Artemis", Space News, 12-18 June 1995, pp. 3, 37.
20. "BAe on ARTEMIS", Space, December 1992 - February 1993, p. 5.
21. P.B. de Selding, "Britain May Abandon Artemis", Space News, 19-25 June 1995, p. 8.
22. B.I. Edelson, et al, NASA/NSF Panel Report on Satellite Communications Systems and Technology, Vol. I, Analytical Chapters, July 1993, pp. 218-241.

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23. B.I. Edelson, op. cit., pp. 241-250.
24. R. Riccitiello, "ESA Works to Improve Telecommunications", Space News, 27 April-3 May 1992, p. 6, 8.
25. "Future ESA Space Plan Agreed", Spaceflight, December 1992, p. 376.
26. R. Riccitiello, "ESA Goes Ahead With Data Relay Satellite Plans", Space News, 12-18 October 1992, p. 1, 28.
27. C. Covault, "Europe Sets \$26-Billion Space Program for 1990's", Aviation Week and Space Technology, 16 November 1992, p. 23-25.
28. "Newsmaker Forum", Space News, 22-28 February 1993, p. 22.
29. "Europe Seeks Military Funds for DRS System", Space News, 27 March - 2 April 1995, p. 2.
30. B.I. Edelson, op. cit., pp. 252-258.
31. R. Riccitiello, "ESA Archimedes Project to Use Elliptical Orbits", Space News, 18-24 May 1992, p. 10.
32. R. Riccitiello, "Alenia Wins ESA Contract for Communications System", Space News, 5-11 October 1992, p. 10.
33. D.J. Marcus and R. Riccitiello, "ESA To Fund Satellite Telephone Technology", Space News, 1-7 February 1993, pp. 4, 21.
34. P.B. de Selding, "Report Urges Europe To Focus on Satellite Communications", Space News, 17-23 January 1994, p. 3.
35. P.B. de Selding, "ESA Communications Funding Frustrates Firms", Space News, 11-17 April 1994, pp. 12-13.
36. "Eutelsat Signs 13 Contracts for Space on Hot Bird 1", Space News, 24-30 October 1994, p. 11.
37. "Eutelsat Hot Bird 1 Starts Direct-Broadcast Service", Space News, 8-14 May 1995, p. 14.
38. "Eutelsat Seeks Bids for Hot Bird Plus Bird", Space News, 1-7 November 1993, p. 2.
39. P.B. de Selding, "Matra Marconi Receives Hot Bird Plus Contract", Space News, 4-10 April 1994, p. 3.
40. "'Hot Bird-3' Commande A Matra Marconi", Air & Cosmos, 16 December 1994, p. 35.
41. "Europe's Largest Array Planned for New Satellite", Space News, 19-25 September 1994, p. 12.
42. "High Power TV Satellite", Spaceflight, June 1994, p. 182.
43. "Eutelsat To Pick Smaller Satellite for Next Series", Space News, 31 May - 6 June 1993, p. 2.
44. P.B. de Selding, "Eutelsat Seeks Bids for Seven Satellites", Space News, 26 September - 2 October 1994, p. 3.

45. "EUTELSAT Gives Green Light for Third Generation", Via Satellite, December 1994, p. 9.
46. P. B. de Selding, "French, Swiss Reluctance May Stall Europesat", Space News, 26 October-1 November 1992, p. 12.
47. P.B. de Selding, "Germans, French Study Possible Astra Competitor", Space News, 7-13 June 1993, p. 4.
48. P.B. de Selding, "Telekom Decides To Drop Europesat", Space News, 24-30 May 1993, pp. 1, 20.
49. CNES Annual Report 1990, CNES, 1991.
50. A Lightning Tour Through CNES, CNES, 1992.
51. Telecom 2 technical brochure, Matra Marconi Space, 1992.
52. "French Expected To Order Fourth Telecom 2 Satellite", Space News, 7-13 June 1993, p. 12.
53. P.B. de Selding, "France Telecom Backs Mobile Systems", Space News, 12-18 September 1994, p. 10.
54. "French Study Coordinating Defense, Civil Telecom Use", Space News, 24-30 June 1994, p. 18.
55. T. Pirard, "DBS to Begin in Europe", Spaceflight, January 1988, p. 24-25.
56. C. Covault, "French Agency Criticizes Management of Communications Satellite Program", Aviation Week and Space Technology, 3 August 1992, p. 22.
57. S80T Micro-Satellite, specification and program sheet, Matra Marconi Space, 1992.
58. P. Jung, "TAOS: A Low Cost Satellite", Paper IAF-93-M.4.333, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
59. J.M. Lenorovitz, "Concepts Reflect Growing Interest in Using Low-Earth Orbit for Data and Voice Relay", Aviation Week and Space Technology, 14 October 1991, p. 74.
60. P.B. de Selding, "French Testing Mobile Technology", Space News, 5-11 October 1992, p. 18.
61. P.B. de Selding, "Taos Work May Start in Early '94", Space News, 27 September - 3 October 1993, pp. 4, 29.
62. "CNES Nears Decision On Go-Ahead for Taos", Space News, 7-13 February 1994, p. 2.
63. "French Offer To Donate Satellite", Space News, 10-16 April 1995, p. 17.
64. P.B. de Selding, "French Envision Arsene as Start of New Trend", Space News, 26 April - 2 May 1993, pp. 4, 21.
65. P.B. de Selding, "French Optimistic Arsene Will Function Adequately", Space News, 24-30 May 1993, p. 10.

66. P.B. de Selding, "Engineers Say Little Hope Remains for Reviving Arsene", Space News, 11-17 July 1994, p. 16.
67. P.B. de Selding, "Telecommunications Industry May Get Boost", Space News, 1-7 November 1993, pp. 7, 9.
68. "France Ready To OK Stentor Satellite Project", Space News, 13-19 June 1994, p. 2.
69. P.B. de Selding, "French Up Military Spending", Space News, 10-16 October 1994, pp. 1, 20.
70. TV Sat. A German Broadcasting Satellite for Direct Reception, brochure issued by Deutsche Telekom, undated.
71. TV-Sat Service Areas, brochure issued by Deutsche Telekom, undated.
72. P.B. de Selding, "Telekom To Stop Buying Satellites", Space News, 23-29 May 1994, pp. 1, 28.
73. C. Bulloch, "Deutsche Telekom, Creeping Toward Privatization", Via Satellite, March 1994, pp. 56-62.
74. DFS Kopernikus. Three Satellites For Every Type of Communication, brochure issued by Deutsche Telekom, February 1993.
75. Launch of the German Telecommunications Satellite DFS 3 Kopernikus, brochure issued by Deutsche Telekom, 1992.
76. I. Parker, "GSOC Delivers DFS-3", Space, March 1993, pp. 22-23.
77. P.B. de Selding, "OHF System Provides Loan To Secure Launch", Space News, 17-23 October 1994, pp. 3, 21.
78. C. Lardier, "Le SAFIR-R1 Lance Avec Resource-03 Par Zenith", Air & Cosmos, 18 November 1994, p. 39.
79. Asiasat 1 and Asiasat 2 Fact Sheets, Asia Satellite Telecommunications Co., Ltd., undated.
80. "Newsmaker Forum", Space News, 25 April - 1 May 1994, p. 22 and 27 February - 5 March 1995, p. 22.
81. P. Seitz, "Second Asiasat Satellite Eight Months Behind Schedule", Space News, 5-11 June 1995, pp. 3, 29.
82. "Satellite Parking Pact Reached", Aviation Week and Space Technology, 4 October 1993, p. 19.
83. P. Seitz, "APT Joins Asian Fray", Space News, 16-22 August 1993, pp. 1, 20.
84. P. Seitz, "APT Readies Pair of Apstar Satellites for Asian Competition", Space News, 4-10 April 1994, p. 23.
85. P. Seitz, "Apstar Draws Fire From Other Asian Operators", Space News, 25-31 July 1994, pp. 3, 20.
86. "China Plans Apstar-1 Checkout, Denies Possibility of Interference", Aviation Week and Space Technology, 8 August 1994, p. 70.

87. P. Seitz, "APT Continues To Spar With Neighboring Pacific Satellites", Space News, 8-14 August 1994, p. 18.
88. P. Seitz, "Apstar Operator Skirts Interference Issue, Lease Tonganese Slot", Space News, 12-18 September 1994, p. 18.
89. "APT Opts To Buy Hughes' Apstar 2", Space News, 6-12 December 1993, p. 10.
90. S. Parnes, "Hungary Assumes Anchor Role on Commercial Satellite", Space News, 8-14 May 1995, p. 20.
91. Annual Report, Department of Space, India, 1983-1984, 1984-1985, 1985-1986, 1986-1987, 1988-1989. See also, U. R. Rao, et al, "The Indian National Satellite System-INSAT", Space Communication and Broadcasting, 1987, p. 339-358.
92. J. M. Lenorovitz, "India Seeks Larger Role in Commercial Satellite Market", Aviation Week and Space Technology, 27 July 1992, p. 57.
93. U. R. Rao, "Space Helps India Develop", Part 2, Space, November-December 1988, p. 15, 17-18.
94. All-India Radio, 23 July and 10 August 1993.
95. All India Doordarshan Television, 15 August 1993.
96. J.M. Lenorovitz, "Ariane-Proton Team Seeks Indian Contracts", Aviation Week and Space Technology, 16 August 1993, pp. 24-25.
97. P.B. de Selding, "Proton Officials Shrug Off Arianespace Bid", Space News, 30 August - 5 September 1993, pp. 3, 21.
98. P.B. de Selding, "Arianespace Receives Contract for Indian Launches", Space News, 14-20 March 1994, p. 3.
99. P. Seitz, "Intelsat To Lease Transponders on Future Indian Satellite", Space News, 9-15 January 1995, p. 16.
100. W. Ferster and P.B. de Selding, "Indians Dive Into Mobile Market", Space News, 23-29 January 1995, pp. 1, 20.
101. P.B. de Selding, "ASC Touts Former Military Technology", Space News, 3-9 July 1995, p. 10.
102. "Innovation From India", Apogee, Hughes Space News, July 1995.
103. P. Seitz, "A Slot War in Pacific Rim Ends", Space News, 8-14 November 1993, p. 16.
104. "Tonga, Indonesians Agree To Share Pacific Ocean Orbital Position", Satellite News, 8 November 1993, pp. 1-3.
105. P. Seitz, "Firms Request Tongasat Sanctions", Space News, 6-12 September 1993, pp. 3, 21.

106. "Tonga and Indonesia Remain At Loggerheads Over GEO Rights", Space Fax Daily, 6 August 1993, p. 1.
107. "Gorizont Satellite Arrives in the Pacific, Indonesia Holds Firm", Satellite News, 26 July 1993, pp. 1-3.
108. Radio Republic of Indonesia, 20 March 1993.
109. M. Mecham, "Ariane Breaks U.S. Hold On Indonesian Launches", Aviation Week and Space Technology, 5 July 1993, p. 71.
110. P. Seitz, "Asia-Pacific Satellite Firms Race To Add New Leases", Space News, 27 March - 2 April 1995, p.19.
111. P. Seitz and P.B. de Selding, "German Firm Buys Stake in Satelindo; Eyes Pacific Market", Space News, 27March - 2 April 1995, p. 4.
112. P. Seitz, "Indonesian Firm Signs on With CTA Subsidiary", Space News, 13-19 December 1993, p. 24.
113. "Industry Outlook", Aviation Week and Space Technology, 9 May 1994, p. 17.
114. P. Seitz, "\$600 Million Secured For Asian Satellite Venture", Space News, 22-28 May 1995, p. 4.
115. "Harris Aerospace Provides L-Band Antennas for ACES", Space News, 29 May - 4 June 1995, p. 12.
116. "Lockheed Martin Signs Asian Satellite Contract", Space News, 10-16 July 1995, p. 2.
117. Inmarsat-3, Mobile Satcoms Payload, technical brochure distributed by Matra Marconi Space, 1992.
118. C. Simpson, "Inmarsat-3, A Satellite Ahead of its Time", Spaceflight, January 1993, p. 18-19.
119. "INMARSAT Council Gives Nod To New Satellite", Space News, 15 March 1994, p. 10
120. "Inmarsat 3 Satellites Face One-Year Delay", Space News, 14-20 November 1994, p. 2.
121. P.B. de Selding, "Inmarsat Offers Incentive", Space News, 5-11 December 1994, p. 1.
122. P.B. de Selding, "Inmarsat Takes Steps Toward Privatization", Space News, 18-24 October 1993, pp. 1, 34.
123. P.B. de Selding, "Groups Urged to Shed Satellite Monopolies", Space News, 13-19 December 1993, pp. 4, 29.
124. P.B. de Selding, "A Dozen Firms Compete for Inmarsat Study Contracts", Space News, 15-21 February 1993, p. 18.
125. P.B. de Selding, "Inmarsat Outlines Trio of Plans For Project 21 Satellite System", Space News, 29 March - 4 April 1993, p. 14.
126. P.J. Klass, "Inmarsat Orbit To Impact Aviation", Aviation Week and Space Technology, 29 March 1993, pp.58-59.



127. P.B. de Selding, "Inmarsat Drops LEO Concept", 2-8 August 1993, pp. 3, 21.
128. P.B. de Selding, "Inmarsat Weighs Two Alternative Proposals For Its Mobile Service", Space News, 9-15 August 1993, p. 8.
129. P.B. de Selding, "Inmarsat's Council Stalls Satellite Plan", Space News, 7-13 March 1994, pp. 1, 28.
130. P.B. de Selding, "Inmarsat Takes First Step To Privatization", Space News, 16-22 May 1994, pp. 1, 20.
131. "Inmarsat Affiliate To Operate Medium-Altitude Satellite System", Aviation Week and Space Technology, 23 May 1994, p. 58.
132. P.B. de Selding, "Inmarsat P Secures Support", Space News, 30 January - 5 February 1995, pp. 1, 10.
133. "News Breaks", Aviation Week and Space Technology, 24 July 1995, p. 17.
134. P. Seitz, "Intelsat Defers Move Into DBS Market", Space News, 27 June - 3 July 1994, pp. 4, 18.
135. F. Shahrokhi and M. Talebzadeh, "Zohreh Satellite System: The Iranian Satellite System", Paper IAF-93-M.5.340, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
136. "Iranian Domestic Satellite System", Space FAX Daily, 8 November 1993, p. 1.
137. "Iranians Could Lease Intelsat 507 Capacity", Space News, 16-22 January 1995, p. 2.
138. M. Williamson, "The AMOS Technology Leap", Space News, January-February 1995, pp. 19-21.
139. "Israeli Firm To Push 'AMOS-1' Services" and "AMOS Services Could Reach Global Proportions", Space FAX Daily, 30 July 1993, p. 1.
140. S. Fisher, "Israel Joins Up", Space, January -February 1991, p. 12-14.
141. S. Parnes, "Funds Sought for Amos Project", Space News, 20-26 April 1992, p. 18.
142. "Ministers Approve 1993 Launch of IAI's Amos Satellite", Aerospace Daily, 9 June 1989, p. 410.
143. "Israeli Satellite Advances", Signal, December 1989, p. 10.
144. A. Tal, "Israel in Space", Spaceflight, October 1993, pp. 344-345.
145. T. Pirard, "Small is Beautiful", Spaceflight, April 1995, pp. 122-123.
146. INTESPACE press release, 11 July 1994.
147. S. Parnes, "Israeli Students Begin Work on Techsat 1 Satellite", Space News, 31 August - 6 September 1992, p. 34.
148. ITAR-TASS News Agency, 1 November 1994.

149. "Italsat Satellite Undergoes Tests in Toulouse, France", Space News, 8-14 August 1994, p. 14.
150. C. Covault, "CNES, Matra Accelerate Spacecraft, Ariane 5 Tests", Aviation Week and Space Technology, 5 December 1994, p. 22.
151. R. Riccitiello, "Italsat Launch to Improve Telecommunications", Space News, 16-22 March 1992, p. 8.
152. B.I. Edelson, op. cit., pp. 250-252.
153. "More Piggy-Back Satellites", Spaceflight, December 1992, p. 384.
154. Novosti Kosmonavtiki, 30 August - 12 September 1993, pp. 20-21.
155. R. Riccitiello, "Telespazio Readies Temisat Satellite for Summer Launch", Space News, 19-25 April 1993, p. 24.
156. P.B. de Selding, "Temisat Launched by Russian Cyclone", Space News, 6-12 September 1993, p. 10.
157. P. Langereaux, "Temisat, Premier Satellite De Telespazio, Construct en Allemagne Et Lance De Russie", Air & Cosmos, 19 September 1993.
158. "Italian Radio Hams Launch a Space Enterprise", Space, March 1993, p. 35.
159. R. Riccitiello, "Ham Radio Group Lures Epson, Coca Cola as Satellite Sponsors", Space News, 10-16 May 1993, p. 17.
160. "ITAMSAT Details", Spaceflight, March 1994, p. 95.
161. NASDA, National Space Development Agency of Japan, 1994, pp. 17-18, 37.
162. NASDA Report, No. 36, June 1995, p. 1.
163. E. Sekigawa, "Japanese Satellite in Errant Orbit", Aviation Week and Space Technology, 5 September 1994, p. 47.
164. S. Mansfield, "Japan's ETS-6 To Highlight Prowess in Space Systems", Space News, 11-17 April 1994, p. 22.
165. S. Mansfield, "New Engine Fails, Stranding ETS-6", Space News, 5-11 September 1994, pp. 1, 20.
166. T. Sienko, "No Kick for Kiku", Space, November-December 1994, pp. 8-10.
167. "Solar Radiation Strikes Another Blow To ETS-6", Aviation Week and Space Technology, 3 October 1994, p. 66.
168. S. Mansfield, "ETS-6 Failure Report Expected by Year's End", Space News, 5-11 December 1994, p. 6.
169. S. Mansfield, "ETS-6 Achieves Many Objectives", Space News, 10-16 April 1995, p. 18.

170. B.I. Edelson, op. cit., pp. 278-280.
171. "Cellsat Study", Aviation Week and Space Technology, 8 August 1994, p. 13.
172. "NASDA To Seek Funding for Engineering Satellite", Space News, 19-25 September 1994, p. 13.
173. N. W. Davis, "Japan Expands Research on Communications Satellites", Aerospace America, August 1992, p. 22-24.
174. NASDA Report, No. 2, November 1988, pp. 4-5.
175. NASDA. National Space Development Agency of Japan, 1994, pp. 19-20.
176. B.I. Edelson, op. cit, p. 270-277.
177. S. Mansfield, "Japanese Make Progress on Experimental Comets Program", Space News, 27 June - 3 July 1994, p. 8.
178. "Optical Communications Test", Aviation Week and Space Technology, 27 July 1992, p. 13.
179. "Agencies Forge Pact", Space News, 12-18 December 1994, p. 23.
180. "Optical Inter-Orbit Communications", Spaceflight, April 1995, pp. 116-117.
181. B.I. Edelson, op. cit., pp. 259-268.
182. NASDA Report No. 1, August 1988, p. 2-3.
183. "French Build N-Star Unit", Aviation Week and Space Technology, 4 January 1994, p. 54.
184. "Japan Looks to N-Star To Recover Experiment", Space News, 30 January - 5 February 1995, p. 2.
185. "NTT's N-Star-A Spacecraft To Be Complete in January", Space News, 9-15 January 1995, p. 12.
186. D. J. Marcus, "G.E. Maintains Foothold in Key Japanese Market", Space News, 14-20 September 1992, p. 4.
187. P. Proctor, "Broadcast Satellite Bolsters Japan's Troubled Space Program", Aviation Week and Space Technology, 2 September 1991, p. 71.
188. D.J. Marcus, "Japanese Pinpoint Reason Behind Power Problem on BS-3A Satellite", Space News, 18-24 March 1991, p. 16.
189. D.J. Marcus, "Flaw Threatens Japanese Satellite Broadcasts", Space News, 10-16 September 1990, p. 4.
190. W. Boyer, "New Japanese Consortium To Procure Two BS-4s", Space News, 29 March - 4 April 1993, p. 18.
191. P. Ferguson, "Japan's Satellite Services Come Upon Tough Times", Space News, 19-25 April 1993, p. 6.

192. P. Seitz, "Japanese Officials Hope BS-3N Will Break Streak of Bad Luck", Space News, 18-24 July 1994, p. 24.
193. "Hughes Nets Contract for Japanese Satellites", Space News, 3-9 January 1994, p. 2.
194. "News Breaks", Aviation Week and Space Technology, 8 August 1994, p. 17.
195. K. P. Dawson, "Satellite Use Doubles Japanese TV Channels", Space News, 27 July - 9 August 1992, pp. 6, 10.
196. K. P. Dawson, "Communications Satellite Binge Begins to Slow", Space News, 27 July - 9 August 1992, pp. 6, 10.
197. "Hughes Wins JCSAT-3 Contract From Japan", Space News, 1-7 November 1993, p. 2.
198. "Japanese Unit Set To Launch First Hughes 393 Satellite", Aviation Week and Space Technology, 20 February 1989, p. 25.
199. M. Magee, "Two Japanese Satellite Firms Still Negotiating Merger", Space News, 3-9 May 1993, p. 11.
200. S. Mansfield, "Digital Multichannel TV To Begin in Japan", Space News, 17-23 July 1995, p. 6.
201. "Via Super Bird, Satellite Communications Services", Space Communications Corporation, 1993.
202. "Japanese Firm To Launch Super Bird C Craft in 1997", Space News, 3-9 October 1994, p. 12.
203. "Japan's New Superbird C Will Cover Asia Pacific", Space News, 13-19 March 1995, p. 19.
204. P. Seitz, "Superbird Operator Might Break Even in 1995", Space News, 12-18 June 1995, p. 6.
205. M. Senechal, "The Astra Constellation", Space, May-June 1994, pp. 22-25.
206. Astra, Hughes Space and Communications, 1993.
207. "Astra Satellites and European Television", Spaceflight, October 1993, p. 333.
208. "SES To Launch Astra 1F On Proton Booster", Aviation Week and Space Technology, 6 February 1995, p. 64.
209. "SES Exercises Option To Buy Hughes Astra 1H", Space News, 10-16 July 1995, p. 2.
210. S. Chernard, "Malaysia's Fast-Growing Economy ", Via Satellite, June 1995, pp. 38-46.
211. "Hughes in the Asia-Pacific Region", Hughes Space and Communications Company, supplement to Via Satellite, January 1995, pp. 8-11.
212. M. Mecham, "Malaysian Firm Selects Hughes DTU Satellite", Aviation Week and Space Technology, 23 May 1994, p. 58.

213. P. Seitz, "Measat's Purchase May Spur Asian Satellite Trend", Space News, 30 May - 12 June 1994, p. 18.
214. Voice of Malaysia, 13 January 1995.
215. "Hughes Accrues Satellite Orders", Space News, 23-29 January 1995, p. 18.
216. L. Van Horn, Communications Satellites, 3rd Edition, 1987, pp. 122-123.
217. "Communications Systems Form Core of Alliance Identity", Signal, October 1993, pp. 51-53.
218. P.B. de Selding, "NATO Reluctant To Purchase Any More Satellites", Space News, 12-18 September 1994, pp. 1, 21.
219. R. Riccitiello, "Thor Slow To Steal Astra's Thunder", Space News, 1-7 February 1993, p. 16.
220. "Nordic Network", Space News, 14-20 November 1994, p. 17.
221. S. Mehmud, "Pakistan's Space Programme", Space Policy, August 1989, p. 217-226.
222. P. Proctor, "Pakistan's Space Agency Building Second Experimental Satellite", Aviation Week and Space Technology, 10 August 1992, p. 46.
223. Liu Ji-yuan and Min Gui-rong, "The Progress of China's Astronautics", U.S. Space Foundation Space Symposium, January 1987.
224. Min Gui-rong, "China's Long March Catching Up in Space", Space Technology International 1992, p. 91-92.
225. Wu Guoxiang, "China's Space Communications Goals", Space Policy, February 1988, p. 41-45.
226. G. L. May, "China Advances in Space", Spaceflight, November 1988, p. 428-433.
227. Liu Lin-hui, "Development and Flight Performances of China's Satellite Power Systems", Space Power, 1988, p. 261-265.
228. "Chinese Satellites", Aerospace Daily, 1 May 1989, p. 168.
229. "Chinese Satellite", Aviation Week and Space Technology, 2 October 1989, p. 15.
230. Zhongguo Xinwen She News Agency, 24 March 1993.
231. Central People's Broadcasting Station, 11 July 1993.
232. C. Covault, "Space Programs Surge in Asia/Pacific Region", Aviation Week and Space Technology, 21 February 1994, pp. 73-75.
233. "DFH-3 Launched", Aviation Week and Space Technology, 5 December 1994, p. 22.
234. "News Breaks", Aviation Week and Space Technology, 16 January 1995, p. 16.

235. "Loss of China's DFH-3 Tops Meeting Agenda", Space News, 6-12 February 1995, p. 2.
236. "Germans Prepare for Chinese Market", Space, September 1994, pp. 33-34.
237. "German-Chinese Satellite Company", Space, December 1993, p. 26.
238. P.B. de Selding, "Firm Seeks Slice of Chinese Satellite Market", Space News, 29 November - 5 December 1993, p. 6.
239. P.B. de Selding, "DASA, Chinese Create Satellite Joint Venture", Space News, 11-17 July 1994, pp. 1, 20.
240. "DASA-CASC Partnership", Aviation Week and Space Technology, 18 July 1994, p. 84.
241. Xinhua News Agency, 20 September 1994.
242. "German-Chinese Company", Spaceflight, September 1994, p. 296.
243. M. Mecham, "China Seeks Expanded Satellite Linkups", Aviation Week and Space Technology, 3 October 1994, pp. 63-66.
244. Xinhua News Agency, 5 July 1993.
245. Tibet People's Broadcasting Station, 9 and 14 July 1993.
246. China Central Television, 6 August 1993.
247. "American-made Satellite Working Well for China", Space FAX Daily, 21 October 1993, p. 1.
248. "INTELSAT To Buy Spacecraft, Share Satellites With China", Aviation Week and Space Technology, 21 March 1994, p. 63.
249. "Used Satellite Sale Closes", Aviation Week and Space Technology, 16 May 1994, p. 13.
250. P. Seitz, "China To Buy Intelsat Transponders", Space News, 10-16 January 1994, p. 11.
251. "Intelsat Pursues Utilization, Launch Deals with Chinese Firms", Space Business News, 29 March 1994, p. 4.
252. "China Designing Data Satellite for '97 Launch", Space News, 31 January - 6 February 1994, p. 2.
253. P. Seitz, "Launcher, Satellite Activities Increase in Pacific Rim Nations", Space News, 24-30 January 1994, p. 24.
254. P. Seitz, "Politics, Industry Prompt Merger", Space News, 30 January - 5 February 1995, p. 9.
255. P. Seitz, "Philippine Rivalry Threatens To End in Stalemate", Space News, 29 May - 4 June 1995, p. 6.
256. "Aerospatiale To Build Agila Satellites", Space News, 19-25 June 1995, p. 9.

257. Izvestiya, 31 May 1991, p. 6; 21 December 1991, p. 9; and 28 December 1992, p. 3.
258. Gonets technical brochures issued by Applied Mechanics NPO and Precision Instruments NPO, 1991-1992.
259. Aviatsiya i Kosmonavtika, April 1993, pp. 13-15.
261. Y.G. Milov and Y.V. Zonov, "Perspectives of Satellite Communication Development in Russia", Paper IAF-93-M.1.308, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
262. Vestnik Svyazi, 11 November 1994, pp. 6-10.
263. Y. Gornostayev, et al, Proceedings of the International Conference on Satellite Communications. ICSC '94, 18-21 October 1994, Vol. I, pp. 31-34; Vol. II, pp. 113-118.
264. Novosti Kosmonavтики, 17-31 December 1994, pp. 17-19.
265. ITAR-TASS News Agency and Ostankino Television, 26 December 1994.
266. Y. Gornostayev, op. cit., Vol. II, pp. 164-171.
267. Global Space Communication System Coscon, brochure issued by International Innovatory Joint Venture COSCON, Moscow-Omsk, 1990.
268. Trud, Moscow, 30 May 1991, p. 2.
269. Zenit, Astro Info Service, England, March 1991, p. 13 and April 1991, p. 16.
270. Moscow Central Television, 28 February 1991.
271. Sovetskiy Patriot, March 1991, p. 15.
272. Vozdushnyy Transport, April 1992, p. 8.
273. Technical drawings issued by Elas NPO, 1992.
274. Y. Gornostayev, op. cit., Vol. II, pp. 102-105.
275. Signal technical description, International Space Communication Concern (KOSS), 1995.
276. Y. Gornostayev, op. cit., Vol. I, pp. 32, 35-36.
277. J.M. Lenorovitz, "Energia Gains U.S. Backing For Signal Satellite System", Aviation Week and Space Technology, 28 February 1994, pp. 55-57.
278. SPS-Sputnik technical description, Makeyev Russian State Missiles Center, 1995.
279. Y. Gornostayev, op. cit., Vol. II, pp. 107-111.

280. Y. Gornostayev, op. cit., Vol. II, pp. 105-106.
281. Y. Gornostayev, op. cit., Vol. II, pp. 97-101.
282. Y. Gornostayev, op. cit., Vol. II, pp. 118-125.
283. P. Langereux, "Project Bankir", Air & Cosmos, 6 October 1990, p. 33.
284. W. Griethe and P. Kunigk, "The Multi-Purpose Satellite System Elekon", Elbe Space and Technology Dresden GmbH, 1995.
285. "The Elekon System", brochure and supporting documents from Elbe Space and Technology Dresden GmbH, 1995.
286. V. Cheremisin, et al, "'Tsikada-M-UTTH' Multi-Purposes Satellite System", undated paper.
287. Y. Gornostayev, op. cit., Vol. I, pp. 18-31, and Vol. II, pp. 88-96.
288. Moskovskiye Novosti, 15 November 1992, p. 6.
289. R.K. Tchuyan, et al, "Satellite Communications System 'Tyulpan'", Paper IAF-93-M.4.338, 44th Congress of the International Astronautical Federation, 16-22 October 1993.
290. "Soviet Communications Satellite Gorizont", brochure distributed by Licensintorg and GLAVKOSMOS, undated.
291. Presentation by M.A. Sternberg, Chief Operating Officer of Rimsat, Ltd., Washington, 17 November 1992.
292. L. Tucci, "Rimsat To Use Gorizont for Pacific Coverage", Space News, 25-31 January 1993, p. 6.
293. "Newsmaker Forum", Space News, 15-21 March 1993, p. 22.
294. "Rimsat Says Venture Nearing Start Date", Space Business News, 30 March 1993, pp. 1-3.
295. P. Seitz, "Intelsat, Tonga Dispute About Orbital Positions Continues", Space News, 21-27 June 1993, p. 8.
296. "Gorizont Satellite Arrives in the Pacific; Indonesia Holds Firm", Satellite News, 26 July 1993, pp. 1-3.
297. P. Seitz, "Firms Request Tongasat Sanctions", Space News, 6-12 September 1993, pp. 3, 21.
298. "Tonga, Indonesians Agree To Share Pacific Ocean Orbital Position", Satellite News, 8 November 1993, pp. 1-3.
299. P. Seitz, "Rimsat Still Struggles For Industry Recognition", Space News, 29 November - 5 December 1993, p. 4.
300. J.M. Lenorovitz, "Gorizont Launch Boosts Russian Satellite Sector", Aviation Week and Space Technology, 30 May 1994, p. 29.



301. "Direct Broadcasting Satellite 'Ekran-M'", brochure distributed by Applied Mechanics NPO, undated.
302. Y. Gornostayev, op. cit., Vol. II, pp. 171-175.
303. Technical materials provided by Elas NPO and Applied Mechanics NPO, 1992.
304. R. Saunders "Despite Poor Economy, Satellite Business Offers New Opportunities", Space News, 9-15 March 1992, p. 4.
305. V. Kiernan, "New System to Connect Russia, U.S.", Space News, 22 June-5 July 1992, p. 12.
306. "VSAT-System 'Sokol'", brochure distributed by Elbe Space and Technology Dresden GmbH, 1995.
307. Y. Gornostayev, op. cit., Vol. I, pp. 73-76.
308. Two versions of brochures about the Luch spacecraft distributed by Applied Mechanics NPO, undated.
309. C. Lardier, "Satellite-Relais Altair", Air & Cosmos, 25 October 1992, p. 50.
310. Y. Gornostayev, op. cit., Vol. II, pp. 1-6.
311. Various technical brochures about the Gals spacecraft distributed by Applied Mechanics NPO, undated.
312. W. Griethe and F. Schwan, "The Gals Satellite", Via Satellite, May 1995, pp. 64-67.
313. Y. Gornostayev, op. cit., Vol. I, pp. 196-210.
314. I. Tsirlin, et al, "'Gals' - Russian NTV System", Radio, 1994, pp. 3-5.
315. M. Lapina, Delovoy Mir, 14-20 November 1994, p. 12.
316. V. Kiernan, "Soviets To Increase Satellite TV Broadcast Capacity", Space News, 6-12 May 1991, p. 24.
317. Moskovskaya Pravda, 28 January 1994, p. 15.
318. Novosti Kosmonavtiki, 15-28 January 1994, pp. 26-28.
319. "Intersputnik Makes Power Plays in Asia's Voice and Video Markets", Telecommunique Asia, 12 December 1994, pp. 1, 3.
320. Moskovskaya Pravda, 11 February 1994, p. 15.
321. ITAR-TASS News Agency, 4 February 1994.
322. "Russian Plasma Thruster Tests", Aviation Week and Space Technology, 14 March 1994, p. 19.
323. Novosti Kosmonavtiki, 4-17 June 1995, p. 27.

324. "Beijing Company To Buy Two Russian Satellites", Space News, 19-25 December 1994, p. 2.
325. Y. Gornostayev, op. cit., Vol. I, pp. 211-215.
326. ITAR-TASS News Agency, 22 November 1994.
327. "Rimsat, Informcosmos Spar Over Satellite Deal", Space News, 19-25 December 1994, p. 2.
328. Various technical brochures about the Express spacecraft distributed by Applied Mechanics NPO, undated.
329. Various technical brochures about the Arkos spacecraft distributed by Applied Mechanics NPO, undated.
330. Y. Gornostayev, op. cit., Vol. I, pp. 18-24.
331. Various technical brochures about the Gelikon spacecraft distributed by Applied Mechanics NPO, undated.
332. "Gelikon Begins to Gel", Cable & Satellite Europe, September 1989, p. 26.
333. Y. Gornostayev, op. cit., Vol. I, pp. 52-58.
334. D. Hughes, "Soviet-Canadian Joint Venture to Design, Launch Satellites", Aviation Week and Space Technology, 12 November 1990, p. 77-78.
335. B. Knapp, "Com Dev Buys Into Soviet Satellite Venture", Space News, 14-20 October 1991, p. 10.
336. Radio Canada International, 19 June 1992.
337. "Russians, Sov Can Star Formalize Joint Venture", Space News, 6-19 July 1992, p. 14.
338. SovCanStar media release, 24 February 1993.
339. "Russian Satcom", Aviation Week and Space Technology, 1 March 1993, p. 23.
340. P.B. de Selding, "SovCan Star Set Back by May Proton Launch Failure", Space News, 28 June - 11 July 1993, pp. 4, 21.
341. "Spar Putting Finishing Touches on SovCanStar Sat Design", Space FAX Daily, 30 June 1993, p. 1.
342. ITAR-TASS News Agency, 23 November 1993.
343. P.B. de Selding, "Lack of Funds Delays SovCan Star Launch", Space News, 13-19 February 1995, pp. 3, 21.
344. P. Langereux, "Soviet Union and Germany Prepare Romantis", Air & Cosmos, 6 October 1990, p. 36-37.
345. P. B. de Selding, "Germans May Barter Satellites for Troop Withdrawal", Space News, 14-20 October 1991, p. 10.

346. P. B. de Selding, "Germans Test Scaled-Down Romantis Plan", Space News, 14-20 December 1990, p. 6.
347. E. Fellman and L. Friedrichs, "How Romantis Became a Reality", Space Technology International, 1991, pp. 72-73.
348. Fact Sheets for Global Information Systems, Inc., and Globostar by GIS, Inc., 1992.
349. R. Riccitiello, "Russian Bank Funds New Communications Spacecraft", Space News, 12-18 April 1993, p. 18, and "Another Satellite Venture Aims for Asian Market", Space News, 14-20 December 1992, p. 18.
350. Various technical documents on the Coupon spacecraft distributed by Globostar and the Lavochkin NPO, undated.
351. P. Langereux, "Nouveaux Satellites Pour Banquiers Et Hommes D'Affaires En Russie Et Cei", Air & Cosmos, 31 May - 6 June 1993, pp. 38-40.
352. "Russians Adapt Military Technology For Comsats", Aviation Week and Space Technology, 30 August 1993, pp. 58-59.
353. "Russian Company Proposes Satellite Banking System", Space News, 16-22 May 1994, p. 13.
354. G. Lomanov, Literaturnaya Gazeta, 21 September 1994, p. 10.
355. Y. Gornostayev, op. cit., Vol. II, pp. 183-189.
356. Y. Markov, Literaturnaya Gazeta, 14 October 1992, p. 13.
357. N.A. Morozov, "Space Communications System 'Zerkalo' ('Mirror')", Space Bulletin, Vol. 1, No. 2, 1993, pp. 14-17.
358. P. Yevseyev, Finansovyye Izvestiya, 18-24 August 1994, p. 4.
359. Y. Gornostayev, op. cit., Vol. I, pp. 32, 37.
360. Y. Gornostayev, op. cit., Vol. I, pp. 132-139.
361. Various technical documents about the Yamal spacecraft distributed by RKK Energiya, undated.
362. Y. Gornostayev, op. cit., Vol. I, pp. 91-106.
363. Integrated Satellite Information System, Energiya NPO and Energiya-Marathon Association, 1991.
364. Global Space System Based on Theory Space Platforms Utilization, Energiya NPO, 1991.
365. P. B. de Selding, "Energiya to Build Huge Satellite", Space News, 10-16 August 1992, p. 17. See also, Izvestiya, 28 December 1992, p. 3.

366. V. Kiernan, "Russians Develop, Big, Heavy, Cheap Communications Satellite", Space News, 30 November-6 December 1992, p. 26.
367. "Giant Russian Antenna Spells Competition for Mobile Networks", Space Business News, 2 March 1993, pp. 1-2.
368. Y. Gornostayev, op. cit., pp. 222-228.
369. P.B. de Selding, "Arabsat To Sign With Aerospatiale, Not Hughes", Space News, 19-25 April 1993, pp. 2, 18.
370. P.B. de Selding, "Arabsat Choice Ends Long Bidding Battle", Space News, 26 April - 2 May 1993, pp. 4, 21.
371. I. Petrov, Kommersant Daily, 28 October 1994, p. 1.
372. P. Seitz, "Asian Firms Study Mobile Satellite Market", Space News, 15-28 August 1994, p. 3.
373. P. Seitz, "Singapore Plans Satellite for Fixed-Site Service", Space News, 29 May - 4 June 1995, p. 8.
374. Yonhap News Agency, 10 August 1992 and 3 October 1992.
375. R. Riccitiello, "Kitsat-A Launch Is First Step for Korean Space Program", Space News, 24-30 August 1992, p. 10.
376. "South Korea Set for Launch No. 2", Spaceflight, July 1993, p. 246.
377. Yonhap News Agency, 27 September 1993.
378. A. Lawler, "South Korea Plans To Build, Launch Satellites", Space News, 28 May - 3 June 1990, pp. 1, 20.
379. Y. Lee, "South Korea, Taiwan Gear Up To Enter Satellite Era", Space News, 24-30 September 1990, p. 7.
380. W. Boyer, "TRW Wins Bid To Develop Korea Multipurpose Satellite", Space News, 19-25 September 1994, p. 8.
381. "TRW Close To Korean Satellite Pact", Aviation Week and Space Technology, 19 September 1994, p. 19.
382. Via Satellite, June 1995, p. 12.
383. "South Korea and China May Team Up To Develop Regional Comsat", Space FAX Daily, 22 October 1993, p. 1.
384. "Seoul, Beijing Cement Joint Satellite Deal", Space FAX Daily, 8 November 1993, p. 1.
385. T. Kiernan, "South Korea, China To Create Joint Satellite Project", Space News, 31 January - 6 February 1994, p. 16.
386. T. Kiernan, "South Korea Seeks Economic Stimulus From Satellites", Space News, 14-20 September 1992, p. 26.

387. "Newsmaker Forum", Space News, 12-18 April 1993, p. 22.
388. R. Riccitiello, "Hispasat Up; Future of Satellite Unclear", Space News, 14-20 September 1992, p. 12.
389. R. Riccitiello, "Spain, Matra Near Major Milestone", Space News, 7-13 September 1992, p. 8.
390. P.B. de Selding, "Matra Dismisses Spanish Firm", Space News, 15-21 February 1993, pp. 1, 21.
391. "Norway and Sweden Bicker Over Marcopolo Sales", Space FAX Daily, 6 January 1994, p. 1.
392. P.B. de Selding, "Sweden's Booming DBS Demand Beats Available Supply", Space News, 10-16 January 1994, p. 16.
393. P.B. de Selding, "Swedish Company To Seek Supplier For Spacecraft To Replace Tele-X", Space News, 6-12 February 1995, p. 17.
394. J.M. Lenorovitz, "Taiwan Awards Rocsat Contracts", Aviation Week and Space Technology, 12 October 1992, p. 58.
395. Central News Agency, (Taipei), 12 January 1993, 19 April 1994, 11 February 1995, and 29 April 1995.
396. "Taiwan Taps TRW Unit To Make Satellite Core", Space News, 11-17 April 1994, p. 2.
397. Aviation Week and Space Technology, 5 June 1995, p. 19.
398. "Integral Systems To Build Rocsat Ground Equipment", Space News, 19-25 June 1995, p. 11.
399. I. Parker, "Thailand Looks To Orbit", Space, July-August 1993, pp. 9-10.
400. P. Seitz, "Thaicom-1 To Bring Capacity to Laos, Cambodia, Vietnam", Space News, 13-19 December 1993, p. 20.
401. P. Seitz, "Thailand Sees Shinawatra as Entree Into Diverse Markets", Space News, 4-10 April 1994, p. 22.
402. "Shinawatra Sells Out Thaicom C-Band Space", Space News, 3-9 April 1995, p. 2.
403. "Aerospatiale to Build Thaicom 3", Space, January-February 1995, p. 28.
404. P. Seitz, "Brazil, Turkey Add Communications Capacity", Space News, 15-28 August 1994, p. 6.
405. "Turkish Authorities Accept In-Orbit Delivery of Satellite", Space News, 24-30 October 1994, p. 10.
406. "Aerospatiale Begins Model of Turksat 1C Spacecraft", Space News, 4-10 July 1994, p. 12.
407. Ukrainian Radio, 25 September 1992 and 10 February 1994.
408. "Ukrainians Sign Space Agreement With Matra Marconi", Space News, 22-28 February 1993, p. 13.

409. Urayadovyy Kuryer, 3 April 1993, pp. 1, 5.
410. T. Pirard, "Ukraine's Space Programme", Spaceflight, November 1993, p. 370.
411. "Ukraine Getting Its Feet Wet In Global Space Market", Space FAX Daily, 8 November 1993, p. 1.
412. Narodnaya Armiya, 15 December 1993, p. 3.
413. Interfax News Agency, 24 October 1994.
414. "Ukraine Develops Own Programme", Spaceflight, October 1994, p. 331.
415. "Skynet Anniversary", Spaceflight, June 1994, p. 183.
416. "Skynet 2B home for 20th Birthday", Space, May-June 1994, p. 36.
417. P.B. de Selding, "Britain Splits Skynet 4 Contract Between Delta, Ariane", Space News, 28 February - 6 March 1994, p. 10.
418. M. Williamson, "What Future for UK Military Satcoms", Space, March-April 1995, pp. 19-21.
419. "British Consider Joint Military Satellite Project", Space News, 6-12 February 1995, p. 2.
420. Various technical documents distributed by Surrey Satellite Technology Ltd., undated.
421. M.J.M. Meerman, "Overall Programmes at the University of Surrey", SSTL, undated.
422. T. Furniss, "Visionary Approach", Flight International, 26 July - 1 August 1995, pp. 36-37.
423. J.M. Lenorovitz, "ESA Offers Updated Navsat Concept As New Civilian Navigation System", Aviation Week and Space Technology, 25 January 1988, pp. 54-55.
424. CNES Annual Report 1990, CNES, 1991, p. 30-31.
425. Geo-Satellite GFZ-1, press release by GeoForschungsZentrum Potsdam, 1994.
426. B.D. Nordwall, "INMARSAT Offers Plan For Civil GPS", Aviation Week and Space Technology, 7 November 1994, p. 41, and P.J. Klass, "INMARSAT Plan Spurs GPS Debate", Aviation Week and Space Technology, 26 July 1993, p. 23.
427. INMARSAT-3, brochure distributed by Matra Marconi Space, undated.
428. "Laser Reflectors on New Italian Satellite", Spaceflight, September 1988, p. 348.
429. "ASI: Lageos Operational Weeks Ahead of Schedule", Space News, 9-15 November 1992, p. 11.
430. R. Schuiling, "Telescience is Put to the Test", Spaceflight, February 1993, pp. 68-69.

- 431. Space in Japan, 1988-89, Research and Development Bureau, Science and Technology Agency, 1988, p. 16.
- 432. NASDA, National Space Development Agency of Japan, 1994, p. 22.
- 433. Great Wall Industry Corporation brochure, circa 1985, p. 19.
- 434. G. L. May, "China Advances in Space", Spaceflight, November 1988, p. 432,
- 435. Liu Ji-Yuan and Min Gui-rong, "The Progress of China's Astronautics", presented at the U.S. Space Foundation Symposium, Colorado Springs, Colorado, 22 January 1987, p. 6.
- 436. Min Gui-rong, "China's Long March Catching Up in Space", Space Technology International, 1992, p. 92.
- 437. Xinhua News Agency, 13 February 1993.
- 438. Xinhua News Agency, 9 December 1992.
- 439. Polyot, Omsk, Russia, advertising brochure distributed by the Polet PO, 1990-1991.
- 440. Russian Spacecraft Design Short Course, Kaman Sciences Corporation, 1994.
- 441. P. Daly and G. E. Perry, "Recent Developments with the Soviet Union's VHF Satellite Navigation System", Space Communication and Broadcasting, Vol. 4, 1986, p. 51-61.
- 442. P. Daly and G. E. Perry, "Update on the Behavior of the Soviet Union's VHF Satellite Navigation System", Space Communication and Broadcasting, Vol. 5, 1987, p. 379-384.
- 443. The USSR in Outer Space. The Year 2005., Glavkosmos, 1989.
- 444. C. Lardier, "Bilan Du Systeme COSPAS-SARSAT", Air & Cosmos, 30 June 1995, p. 41.
- 445. "Rescue System's Operator Predicts Rapid Expansion", Space News, 20-26 September 1993, p. 13.
- 446. N.L. Johnson, "GLONASS Spacecraft", GPS World, November 1994, pp. 51-58.
- 447. GLONASS Info Bulletin, No. 1, Scientific Information Center, Russian Military Space Forces, January 1994.
- 448. GLONASS Status and Development. An Interim Report, Russian Institute of Radionavigation and Time, 1993.
- 449. A. Romanenko, Novosti Kosmonavтики, 26 February - 11 March 1994, pp. 34-36.
- 450. G. I. Moskin and V. A. Sorochinsky, "Navigational Aspects of GLONASS", GPS World, January-February, 1990, p. 50-54.
- 451. P. Daly, "NAVSTAR GPS and GLONASS - Global Satellite Navigation Systems", Paper IAF-89-396, 40th Congress of the International Astronautical Federation, 7-12 October 1989, Malaga, Spain.

452. P. Raby, S. Riley, and P. Daly, "Initial Results of Integrity Monitoring Tests on GPS/GLONASS", Department of Electronic and Electrical Engineering, University of Leeds, UK, November, 1991.
453. T. G. Anodina, "The GLONASS System Technical Characteristics and Performance", Working Paper FANS/4-WP/75, International Civil Aviation Organization, 6 May 1988, Montreal, Canada.
454. M. Lebedev, "GLONASS, Space Navigation System", Military Parade, September-October 1994, pp. 20-21.
455. "Visit to GLONASS Center Is First for Outsiders", GPS World, September 1993, pp. 16, 18.
456. Yu. G. Gouzhva, et al, "High-Precision Time and Frequency with GLONASS", GPS World, July-August 1992, pp. 40-49.
457. S.A. Dale, I.D. Kitching, and P. Daly, "Position-Fixing Using the USSR's GLONASS C/A Code", IEEE AES Magazine, February 1989, pp. 3-10.
458. P.N. Misra, et al, "GLONASS Performance in 1992: A Review", GPS World, May 1993, pp. 28-38.
459. Navigation Satellite "GLONASS", technical specifications distributed by the Applied Mechanics NPO, Krasnoyorsk, 1991.
460. N. Ivanov and V. Salischev, "GLONASS System - Overview", Institute of Space Device Engineering, November 1991.
461. R. Saunders, "Airline Tests Navigation Satellite Link", Space News, 6-12 May 1991, p. 22-23.
462. B. D. Nordwall, "Flight Tests Highlight New GPS Uses, Emphasize Need for GPS/Glonass System", Aviation Week and Space Technology, 2 December 1991, p. 71-73.
463. P. J. Klass, "Inmarsat Decision Pushes GPS to Forefront of Civil Navsat Field", Aviation Week and Space Technology, 14 January 1991, p. 34-35.
464. D. Hughes, "U.S. and Soviets Offer Civil Aviation Free Access to Satellite Navigation Signals", Aviation Week and Space Technology, 9 September 1991, p. 38.
465. D. Hughes, "ICAO Delegates Back FANS Concept, Set Stage for Global Satellite Systems", Aviation Week and Space Technology, 14 October 1991, pp. 36, 43.
466. P.N. Misra, "Integrated Use of GPS and GLONASS in Civil Aviation", The Lincoln Laboratory Journal, Vol. 6, No. 2, 1993, pp. 231-247.
467. N.E. Ivanov and V. Salistchev, "GLONASS and GPS: Prospects For A Partnership", GPS World, April 1991, pp. 36-40.
468. Yu. Gouzhva, et al, "GLONASS Receivers: An Outline", GPS World, January 1994, pp. 30-36.
469. B.D. Nordwall, "NAVSAT Users Want Civil Control", Aviation Week and Space Technology, 18 October 1993, pp. 57-59.



470. L. Burgess, "Glonass Expected To Be Operational in 1995:", Space News, 4-10 October 1993, p. 6.
471. J.M. Lenorovitz, "Russia Expands GLONASS Network", Aviation Week and Space Technology, 29 August 1994, p. 76.
472. P.J. Klass, "GLONASS-M Readied", Aviation Week and Space Technology, 12/19 December 1994, p. 59.
473. V. Pankonin, Interference to Radio Astronomy from GLONASS Transmissions in the Frequency Band 1600-1615 MHz, National Science Foundation, August 1985.
474. R. J. Cohen, "The Threat to Radio Astronomy from Radio Pollution", Space Policy, May 1989, p. 91-93.
475. V. Kiernan, "Noise Pollution or Navigation?", Space News, 25 February-3 March 1991, p. 4, 29.
476. P. V. Bout, "Protect Radio Astronomers from Noisy Satellites", Space News, 16-22 December 1991, p. 15.
477. Geodetic Satellite GEO-IK, technical specifications distributed by the Applied Mechanics NPO, Krasnoyarsk, 1991.
478. V. S. Avduyevsky and G. R. Uspensky, Scientific and Economy-Oriented Space Systems, Mir Publishers, 1988, p. 212-260.
479. S. K. Tatevian, "The Space Geodetic Complex 'GEO-IK'", CSTG Bulletin, No. 11, International Coordination of Space Techniques for Geodesy and Geodynamics, 1989, p. 9-11.
480. Aviatsiya i Kosmonavtika, February 1993, pp. 38-39.
481. Yu. Rusakov and V. Gorev, Novosti Kosmonavtiki, 19 November - 2 December 1994, pp. 23-24.
482. V. Boykov, et al, Geodeziya i Kartografiya, November 1993, pp. 8-12.
483. S. K. Tatevian and A. N. Zakharov, "The Geodynamical Satellite 'Etalon'", CSTG Bulletin, No 11, International Coordination of Space Techniques for Geodesy and Geodynamics, 1989, p. 3-8.
484. V. P. Bass and S. K. Tatevyan, Astronomicheskii Zhurnal, November-December 1990, p. 1315-1325.
485. V. Ye. Chebotarev, et al, Geodeziya i Kartografiya, December 1993, pp. 8-11.
486. M.P. Nevolko, et al, Geodeziya i Kartografiya, December 1993, pp. 11-14.
487. EUMETSAT, brochure of Meteosat system description, EUMETSAT, 1992.
488. MOP 2, ESA C-6, ESA and EUMETSAT, January 1991.
489. METEOSAT, Aerospatiale, 1992.
490. EUMETSAT Annual Report 1991, EUM AR 04, EUMETSAT, 1991.

491. "Meteosat Programme", Spaceflight, October 1993, p. 337.
492. P.B. de Selding, "Study Says European Weather Satellite Buys Industry", Space News, 15-28 November 1993, p. 21.
493. P.B. de Selding, "Meteosat Ready To Aid U.S. Weather Coverage", Space News, 1-7 March 1993, p. 6.
494. "European, Mexican Payloads Set For Arianespace Launch", Aviation Week and Space Technology, 15 November 1993, p. 30.
495. "Meteosat 6 Assessment", Aviation Week and Space Technology, 3 January 1994, p. 13.
496. "Outlook Bright for Weather Forecasts", Spaceflight, February 1994, p. 71.
497. "Inquiry Board To Investigate Meteosat 6 Anomaly", Space Business News, 15 March 1994, p. 4.
498. "Meteosat 6", Space News, 12-18 December 1994, p. 23.
499. '94 Annual Report, ESA, 1995, pp. 41-45.
500. Bright Eyes, ESA C-7 ESA, April 1991.
501. M. Rosengren, "ERS-1 - An Earth Observer That Exactly Follows its Chosen Path", ESA Bulletin, No. 72, November 1992, p. 76-82.
502. M. Mecham, "Europe's New ERS Satellite Will Advance CO<sub>2</sub>, Weather Studies", Aviation Week and Space Technology, 15 April 1991, pp. 37-39.
503. R. Riccitiello, "ERS-1 Ocean Imaging Exceeds Initial Expectations", Space News, 8-14 June 1992, p. 8.
504. M. Mecham, "Europeans Prepare to Build on Early ERS Satellite Success", Aviation Week and Space Technology, 13 July 1992, p. 68-69.
505. P. B. de Selding, "Dual ERS Operations Sought for '95", Space News, 8-14 March 1993, p. 6.
506. I. Parker, "ERS Handover", Space, January-February 1995, pp. 6-10.
507. R. Riccitiello, "ESA Improves Radar Data Delivery to Researchers", Space News, 19-25 October 1992, p. 17.
508. R. Riccitiello, "Foreign ERS-1 Sites Begin To Hit Stride", Space News, 5-11 April 1993, pp. 3, 21.
509. P.B. de Selding, "ERS-1 Customers Concerned About Slow Imagery Delivery", Space News, 17-23 May 1993, p. 22.
510. N. Longdon, "From Oil Slicks to Green Shoots", Spaceflight, April 1993, pp. 126-127.
511. D.P. Werner, "Salmon Watchers Seek Satellite Data on Ocean Temperatures", Space News, 4-10 July 1994, p. 8.

- 512. C. Covault, "ERS Radar Satellite Scans Global Ocean", Aviation Week and Space Technology, 24 October 1994, pp. 42-43.
- 513. "ERS-1 Craft To Detect Oil Spills", Space News, 14-20 November 1994, p. 21.
- 514. P.B. de Selding, "ERS-1 Faces Early Shutdown", Space News, 20-26 September 1992, pp. 1, 20.
- 515. P.B. de Selding, "Funding Falls Short for ERS-1", Space News, 18-24 July 1994, p. 26.
- 516. "Matra Official Suggests Military Sponsor ERS-1", Space News, 5-11 September 1994, p. 2.
- 517. ERS-2, ESA Launches Best-Ever Ozone Monitor, brochure distributed by ESA, undated.
- 518. Europe and Asia in Space 1991-1992, Appendices 8 and 9.
- 519. C. A. Shifrin, "Polar Platform To Offer Constant Earth Observation", Aviation Week and Space Technology, 29 March 1993, p. 25-26.
- 520. The European Polar Platform for the Envisat-1 Mission, press release issued by ESA, 24 July 1995.
- 521. J. Cendral, "The Polar Platform: A Status Report", Aerospace America, April 1994, pp. 30-33, 43.
- 522. M. Hempzell, "Polar Platform Model Unveiled", Spaceflight, August 1993, pp. 254-255.
- 523. S. Chalkley and J. Simpson, "The Polar Platform, What It Is and What It Provides", Spaceflight, August 1993, pp. 258-261.
- 524. P.B. de Selding, "Envisat Instrument Backed by U.K. Environmental Agency", Space News, 17-23 January 1994, p. 17.
- 525. C.A. Shifrin, "Polar Platform To Offer Constant Earth Observation", Aviation Week and Space Technology, 29 March 1993, pp. 25-26.
- 526. R. Riccitiello, "Australia Funds New ATSR Instrument", Space News, 26 April - 2 May 1993, p. 18.
- 527. "Earth Observation Technology", Spaceflight, January 1995, p. 20.
- 528. P.B. de Selding, "IAF News: China Plans; Alenia Prepares; Metop Shrinks", Space News, 24-30 October 1994, p. 18.
- 529. A. Lawler and P.B. de Selding, "Europe, U.S. Propose Joint Weather Craft", Space News, 16-22 May 1994, pp. 1, 20.
- 530. A. Lawler, "Data Control Complicates Weather Merger", Space News, 20-26 June 1994, pp. 3, 20.
- 531. P.B. de Selding, "Accord on Weather Satellites Likely", Space News, 12-18 December 1994, p. 23.
- 532. P.B. de Selding, "Eumetsat Charts More Independent Course", Space News, 10-16 July 1995, p. 6.

533. R. Saunders, "SPOT Chooses Mid-1998 For Self-Sufficiency", Space News, 21 January-3 February 1991, p. 33.
534. G. Brachet, "The French SPOT Programme", The Cambridge Encyclopedia of Space, 1990, p. 238-241.
535. "SPOT 3 Launch Was an Unforgettable Event", Spaceflight, January 1995, p. 22.
536. B. Iannotta, "POAM Sensors Probe Ozone Hole", Space News, 30 May - 12 June 1994, p. 8.
537. "POAM 2 Begins Operation on SPOT", Aviation Week and Space Technology, 18 October 1993, p. 93.
538. R. Riccitiello, "Retired SPOT 1 May Return to Active Duty in 1993", Space News, 23-29 November 1992, p. 16.
539. R. Riccitiello, "Odetics Upgrade Tape Recorders on SPOT 3", Space News, 30 November-6 December 1992, p. 12.
540. P.B. de Selding, "French Government To Continue SPOT Satellite Funding", Space News, 20-26 September 1993, p. 10.
541. D.P. Werner, "SPOT Imagery Used in Calif. Fire Damage Assessment", Space News, 8-14 November 1993, p. 8.
542. P.B. de Selding, "SPOT Wins Financing To Operate Pair of Satellites in 1994", Space News, 31 January - 6 February 1994, p. 17.
543. W. Ferster, "SPOT Satellite Imagery Finds New Market Niche in 3-D", Space News, 13-19 February 1995, p. 16.
544. C. Covault, "Korean Nuclear Site Revealed", Aviation Week and Space Technology, 11 April 1994, p. 22.
545. "Justice From Space", Aviation Week and Space Technology, 25 July 1994, p. 13.
546. S. Weber, "Imagery Supports Haiti Operations", Space News, 17-23 October 1994, p. 17.
547. S.P. Mertikas and V. Giavi, "Detection of Oil Spills Using SPOT Remote Sensing Data", Earth Space Review, Vol. 4, No. 2, 1995, pp. 19-24.
548. P.B. de Selding, "French Firms To Build Advanced Satellite-Image Recorder", Space News, 13-19 December 1993, p. 24.
549. "EU's Commission Agrees To Split Instrument Costs", Space News, 24-30 January 1994, p. 18.
550. P.B. de Selding, "SPOT Seeks Funding To Update Data Processing, Storage System", Space News, 4-10 April 1994, p. 11.
551. "Une Annee Cle Pour L'Imagerie Satellitaire", Air & Cosmos, 6 January 1995, p. 59.

552. P.B. de Selding, "CNES Selects New Satellite Recorder", Space News, 20-26 February 1995, p. 17.
553. "Newsmaker Forum", Space News, 12-18 June 1995, p. 38.
554. J. M. Lenorovitz, "Spot Image Plans Better Resolution on Next Generation of Satellites", Aviation Week and Space Technology, 15 June 1992, p. 94-97.
555. R. Riccitiello, "France, SPOT Plan New Satellite Design Before 2000", Space News, 25-31 January 1993, p. 18.
556. "France Defines Satellite to Complement Spot Series", Aviation Week and Space Technology, 23 October 1989, p. 48.
557. Study of Our Planet: The French Space Effort, CNES, 1991, p. 25.
558. DARA Information 1991. Space Research for a Global Perspective, DARA, Bonn, June 1991.
559. "DASA Ships Radar For Shuttle Mission", Aviation Week and Space Technology, 26 October 1992, p. 75.
560. Experiments in Space. The Second German Spacelab Mission D-2, DLR, Cologne-Porz, March 1992.
561. MOMS-02, brochure distributed by DARA, DLR, Deutsche Aerospace, AGF, and IFP, 1994.
562. GEO-Information-Systems, Vol. 6, No. 1, 1993, pp. 1-30.
563. MOMS-02-D2 Data Catalogue, DARA, July 1994.
564. Annual Report 1988-89, Department of Space, Government of India, 1989.
565. PTI News Agency, 16 October 1994.
566. All-India Radio, 15 October 1994.
567. "IRS-P2 Remote Sensing Craft Declared Operational", Space News, 21 November - 4 December 1994, p. 17.
568. K.P. Corbley, "EOSAT-India Partnership Broadens International Remote Sensing Market", Earth Space Review, Vol. 3, No. 4, 1994, pp. 20-26.
569. D.F. Robertson, "India Strikes Out for Commercial Gold", Space, March-April 1995, pp. 3-5.
570. V. Raghuvanshi, "Germany to Supply Part for India's IRS-P2", Space News, 8-14 February 1993, p. 20.
571. A. Lawler, "India's IRS-1C Satellite To Offer Sharper Images", Space News, 25-31 May 1992, p. 11.
572. "India Building Follow-On Remote Sensing Spacecraft", Space Fax Daily, 23 November 1992, p. 1.
573. V. Raghuvanshi, "India Prepares Second Generation IRS Spacecraft for 1995 Launch", Space News, 1-7 August 1994, p. 18.

574. W. Ferster, "India Readies Sharper IRS-1C for Molniya Launch", Space News, 9-15 January 1995, p. 3.
575. W. Ferster, "India's Data Policy Stalls Remote-Sensing Ambitions", Space News, 20-26 February 1995, p. 3.
576. "X-SAR Accepted", Space, October 1993, p. 7.
577. J.T. McKenna, "Mission 59 To Survey Earth With Multiband Radar", Aviation Week and Space Technology, 11 April 1994, pp. 64-65.
578. R. Riccitiello, "Italians Weigh Two Approaches for Earth Sensing Satellites", Space News, 8-14 March 1993, p. 18.
579. "Alenia Spazio Negotiates Cosmos Satellite Project", Space News, 20-26 March 1995, p. 11.
580. T. Pirard, "Small is Beautiful", Spaceflight, April 1995, pp. 122-124.
581. Geostationary Meteorological Satellite-4 [HIMAWARI-4], technical brochure distributed by NASDA, 1991.
582. Geostationary Meteorological Satellite-5 [HIMAWARI-5], technical brochure distributed by NASDA, 1991.
583. "Japan's New Space Bid", Spaceflight, April, 1987, p. 138-141.
584. NASDA. National Space Development Agency of Japan, NASDA, 1992, pp. 21-22.
585. N. W. Davis, "Japan Stresses Multisatellite Remote Sensing", Aerospace America, March 1993, p. 28.
586. ERS-1, Earth Resources Satellite-1, NASDA, 1990.
587. K. P. Dawson, "Balky Radar Antenna Threatens JERS-1 Mission", Space News, 17-23 February 1992, p. 3, 21.
588. "Controllers Struggle With Radar Antenna on JERS-1 Satellite", Aviation Week and Space Technology, 17 February 1992, p. 21.
589. "Japanese Relief as JERS-1 Antenna Finally Deploys", Spaceflight, June 1992, p. 188.
590. K. P. Dawson, "JERS Producing Flawed Imagery", Space News, 14-20 December 1992, p. 22.
591. "JERS-1 Sends First SAR Image", Spaceflight, July 1992, p. 218.
592. B. Iannotta, "Japanese Imagery Sales Disrupted By Price Dispute", Space News, 26 July - 1 August 1993, pp. 4, 21.
593. "Japan Earth Resources Sat Goes Belly Up", Space FAX Daily, 7 January 1994, p. 1.
594. "Japanese Remote-Sensing Satellite Develops Problem", Space News, 24-30 January 1994, p. 19.
595. "Company Starts Building JERS-1 Data Processor", Space News, 10-16 April 1995, p. 12.

596. ADEOS. Advanced Earth Observing Satellite, NASDA, undated.
597. P. Proctor, "Japan Plans New Generation of Remote Sensing Satellites", Aviation Week and Space Technology, 13 July 1992, p. 66-67.
598. D. J. Marcus, "Japan Plans Missions for Earth Observation", Space News, 18-24 March 1991, p. 23.
599. "NASDA To Pick Payloads For Successor to Adeos", Space News, 1-7 November 1993, p. 11.
600. "Honeywell Chosen To Build ADEOS SeaWinds Antenna", Space News, 30 January - 5 February 1995, p. 13.
601. T. Sakata, "Japan's New Long-Term Space Vision: Creating a Space Age in the New Century", Earth Space Review, Vol. 4, No. 2, 1995, pp. 5-9.
602. Kyodo News Services, 14 May 1993.
603. W. Ferster, "Goddard Scientists Eye TRMM Follow-On Spacecraft", Space News, 3-9 July 1995, p. 16.
604. Radio Pakistan, 8 January and 27 February 1993.
605. "Pakistan To Rocket Second Satellite Into Space Next Year", Space FAX Daily, 11 June 1993, p. 1.
606. Pakistan TV, 25 February 1994.
607. S. Mehmud, "Pakistan's Space Programme", Space Policy, August 1989, p. 217-226.
608. P. Proctor, "Pakistan's Space Agency Building Second Experimental Satellite", Aviation Week and Space Technology, 10 August 1992, p. 46.
609. Lin Hua-bao and Min Gui-rong, "The Chinese Recoverable Satellite Program", Paper IAF-89-426, 40th Congress of the International Astronautical Federation, October 1989.
610. Recoverable Satellite FSW. Microgravity Test Platform, Chinese Academy of Space Technology, 1987.
611. Lin Hau-bao and Min Gui-rong, "Aspects of the China's Recoverable Satellite Platform", Paper IAF-93-U.2.552, 44th Congress of the International Astronautical Federation, October 1993.
612. J. Zhaogian and G. Lynwood-May, "China's Developing Space Program", Signal, February 1986, p. 27.
613. H. Changchui, "The Development of Remote Sensing in China", Space Policy, February 1989, p. 65-74.
614. Liu Ji-yuan and Min Gui-rong, "The Progress of China's Astronautics", U.S. Space Foundation Symposium, Colorado Springs, 1987.
615. Xinhua News Agency, 8 and 18 October 1993.
616. "LM-2C Placed a Satellite Into LEO", press release, China Great Wall Industry Corporation, 28 October 1993.

617. Reuter (Beijing), 18 October 1993.
618. UPI (Beijing), 27 December 1993.
619. "First Recovery Failure for Chinese FSW-1 Satellite", Jane's Intelligence Review, December 1993, p. 6.
620. "PRC Failure Creates Risk", Aviation Week and Space Technology, 25 October 1993, p. 71.
621. Space in China. Launch Services and Space Technology, China Great Wall Industry Corporation, 1989.
622. Chuijun Weng, et al, "Remote Sensor on the FY-1 Satellite", Paper IAF-92-099, 43rd Congress of the International Astronautical Federation, August-September 1992.
623. C. Covault, "Chinese Seek U.S. Assistance in Weather Satellite Program", Aviation Week and Space Technology, 5 August 1985, p. 79-81.
624. Min Gui-rong, "China's Long March Catching Up in Space", Space Technology International, 1992, p. 91-92.
625. T. Pirard, "Earth Observation Technology", Spaceflight, January 1995, pp. 20-21.
626. Xinhua News Agency, 13 January 1993 and 8 April, 25 March, and 24 May 1994.
627. Reuter (Beijing), 25 April 1994.
628. A. Lawler, "Chinese Weather Satellite To Offer Continuous Coverage", Space News, 31 January - 6 February 1994, p. 8.
629. M. Mecham, "Blast in China Unlikely to Halt Launches", Aviation Week and Space Technology, 2 May 1994, p. 24.
630. A. Lawler, "Blast at Xichang Derails China's Weather Effort", Space News, 2-8 May 1994, p. 3.
631. "Feng Yun-2 Successor Slated for '95 Launch", Space News, 24-30 October 1994, p. 2.
632. China-Brazil Resources Satellite-CBERS, technical brochure, Instituto Nacional de Pesquisas Espaciais, 1992.
633. Chen Fang-yun, et al, "Earth Environment Observing Satellite System and International Cooperation", Paper IAF-92-138, 43rd Congress of the International Astronautical Federation, August-September 1992.
634. PoSAT-1 Microsatellite, technical specification sheet distributed by Surrey Satellite Technology Ltd., 1993.
635. "First PoSAT Images", Space, December 1993, p. 6.
636. "Remote Sensing by Microsatellite", Spaceflight, February 1994, p. 71.
637. Pravda, 3 February 1992, p. 3



638. Izvestiya, 17 September 1992.
639. Novosti Kosmonavтики, 30 August - 12 September 1993, pp. 20-21.
640. Information on Meteorological and other Environmental Satellites, Second Edition, WMO-No. 411, World Meteorological Organization, 1989, p. V-10-V-16.
641. "Meteor-3" Space Station for Hydrometeorological Observation, Soviet Association for Earth Remote Sensing and the All-Union Research Institute of Electromechanics, 1991.
642. Automatic Spacecraft "Meteor-3", V/O Sovelectro, 1989.
643. "Soviets to Test-Fly a Meteor 3 Before August TOMS Launch", Aerospace Daily, 24 January 1991, p. 134.
644. Pravda, 15 August 1991, p. 3 and 17 August 1991, p. 2.
645. Izvestiya, 16 August 1991, p. 1-2; 19 August 1991, p. 3; and, 16 September 1991, p. 2.
646. D. Isbell, "Soviets To Launch U.S. Ozone Mapper", Space News, 5-18 August 1991, p. 14.
647. C. Covault, "Soviets Open Plesetsk to U.S. Group for Joint Satellite Mission Launch", Aviation Week and Space Technology, 19 August 1991, p. 30.
648. "TOMS Working Properly, Cooperation Progressing", Space News, 2-8 December 1991, p. 20.
649. "'Meteor-3' - TOMS", Man and Space, No. 1, 1992, p. 25.
650. "Key Ozone Mappers Fail", Aviation Week and Space Technology, 21 June 1993, p. 81.
651. "TOMS Sensor Measures Most Severe Ozone Hole", Space News, 1-7 November 1993, p. 11.
652. "TOMS Mission Declared Over by NASA Officials", Space News, 20-26 February 1995, p. 11.
653. Izvestiya, 17 September and 29 December 1992.
654. Study of Our Planet: The French Space Effort, CNES, 1992, p. 14-17.
655. "French, German Payloads Set for Russian Flight", Aviation Week and Space Technology, 10 January 1994, p. 31.
656. S. Ivanov and K. Lantratov, Novosti Kosmonavтики, 15-28 January 1994, pp. 30-34.
657. V. Tezin, Gudok, 1 April 1994, p. 4.
658. Spacecraft "Meteor-3M" Reference Book, USSR State Committee for Hydrometeorology, Ministry of the Electrotechnical Industry, 1990.
659. Interfax News Agency, 16 December 1994.

660. A.K. Kuzmin and K.N. Chikov, Kosmicheskiye Issledovaniya, January-February 1994, pp. 126-142.
661. Space System with Geostationary Meteorological Satellite (GOMS), Soviet Association for the Earth Remote Sensing, 1991.
662. Information on Meteorological and Other Environmental Satellites, op-cit., p. V-26-V-28.
663. "Russians Plan 1993 Launch of GOMS Weather/Telecom Satellite", Aviation Week and Space Technology, 1 June 1992, p. 70-71.
664. Novosti Kosmonavtiki, 22 October - 4 November 1994, pp. 40-41 and 19 November - 2 December 1994, pp. 27-29.
665. "New Russian Metsat Launched", Spaceflight, January 1995, p. 14.
666. V. Makashin, Krasnaya Zvezda, 5 November 1994, p. 3.
667. C. Lardier, "La Russie Va Enfin Lancer Le Premier GOMS", Air & Cosmos, 21 October 1994, p. 34.
668. V.M. Agapov, Novosti Kosmonavtiki, 22 October - 4 November 1994, pp. 49-51.
669. NTV Television (Moscow), 11 October 1994.
670. Resours-O Space System for Ecological Monitoring, Soviet Association for the Earth Remote Sensing, 1991.
671. Multispectral Space Imaging of the Earth. Space Remote Sensing System "Resource-O1", two versions, GLAVKOSMOS, 1991.
672. State-of-the-Art and Prospects for Earth Resources and Hydrometeorological Satellite System Development, USSR State Committee for Hydrometeorology, State Research Center for Earth Resources Exploration, 1988, p. 31-36.
673. Y. Israel, et al, "The Space Ecological Monitoring of Cities and Suburban Areas with the Use of 'Resource-O1' Satellite", Paper IAF-89-143, 40th Congress of the International Astronautical Federation, 7-12 October 1989.
674. Preliminary Technical Description of Commercial Remote Sensing Capability, GLAVKOSMOS and Space Commerce Corporation, 1989.
675. Y. Novikov and A. Dula, "Ecological Monitoring from Space", 1991.
676. Y. Trifonov, "Commercial Spacecraft for the Exploration of the Earth's Natural Resources", All-Union Science Research Institute of Electromechanics, 1989.
677. A. S. Selivanov, et al, "Basic Parameters of Terrestrial Reception Facilities and Recording Systems of 'Resource'", 1989.
678. Information from the "Resurs-O1 No. 2 Satellite", 1989.

679. Information on Meteorological and Other Environmental Satellites op-cit. p. V-23-V-25.
680. Small Stations for Reception of Information from Spacecraft of "Resurs" System Used for Exploration of Natural Resources, GLAVKOSMOS, 1990.
681. Novosti Kosmonavтики, 22 October - 4 November 1994, pp. 46-47 and 5-18 November 1994, pp. 31-33.
682. ITAR-TASS News Agency, 4 November 1994.
683. "Zenit Rocket Launches German Safir Payload", Space News, 7-13 November 1994, p. 2.
684. P.B. de Selding, "OHF System Provides Loan To Secure Launch", Space News, 17-23 October 1994, pp. 3, 21.
685. J.M. Lenorovitz, "Russia Targets May Launch For Earth-Imaging Satellite", Aviation Week and Space Technology, 18 April 1994, p. 55.
686. Vechernyaya Moskva, 4 March 1994, p. 4.
687. Yu. V. Trifonov, "The Russian Space Earth Observation System 'Resurs-O'", Space Bulletin, Vol. 1, No. 2, 1993, pp. 11-13.
688. I. B. Afanasyev, "Unknown Spacecraft", Izdatelstvo Znaniye, December 1991.
689. H. A. Yefremov and W. B. Wirin, "Almaz Satellites", Paper IAF-91-153, 42nd Congress of the International Astronautical Federation, 1991.
690. D. Massonnet, et al, "Advanced Use of Almaz Radar Data", Paper IAF-92-108, 43rd Congress of the International Astronautical Federation, 1992.
691. Almaz. Radar Remote Sensing Satellite. Buyer's Guide, Space Commerce Corporation, 1990.
692. Radar Data Processing Center Structure Technical Proposal, Special Design Section, Moscow Energy Institute, 1989.
693. "Collapse of Russian Economy Threatens Almaz Radar Spacecraft Program", Aviation Week and Space Technology, 3 February 1992, p. 57.
694. V.V. Viter, "The 'Almaz' Program and the Development of Remote Sensing Techniques to Study the Earth from Space", Space Bulletin, Vol. 1, No. 1, 1993, pp. 14-19.
695. P.B. de Selding, "Russian Firm Expects 1996 Launch of Next Almaz Radar Satellite", Space News, 17-23 May 1993, p. 22.
696. Kuranty, 25 June 1993, p. 3.
697. Vechernyaya Moskva, 2 August 1993, p. 7.

698. Vozdushnyy Transport, September 1993, p. 6.
699. G. Yefremov, "The Almaz Heritage", Space, May-June 1994, pp. 26-28.
700. D. Kholodov, Moskovskiy Komsomolets, 16 June 1994, pp. 1-2.
701. Interfax News Agency, 19 December 1994.
702. W. Ferster, "Almaz Technology Basis for New U.S.-Russian Venture", Space News, 26 June - 2 July 1995, p. 27.
703. The Earth Radar Remote Sensing Spacecraft Almaz, Mashinostroenia NPO, undated.
704. V. F. Pankin, Soviet Satellite Cameras, Soyuzkarta, 1989.
705. "Description of the Information Obtained from Resource-F Earth Observation Spacecraft", Soyuzkarta, 1989.
706. Technical documents provided by National Remote Sensing Centre Limited offering imagery products from Resurs-F1 spacecraft, 1994.
707. "Russian Imagery from NSRC", Space, December 1993, p. 4.
708. E.L. Lukashevich, "The Space System 'Resurs-F' for the Photographic Survey of the Earth", Space Bulletin, Vol. 1, No. 4, 1994, pp. 2-4.
709. G. P. Anshakov, et al, "Earth Resources and Research Automated Spacecraft", Photon Design Bureau, Kuybyshev, 1989.
710. "Resurs-F3 Identified", Space, March-April 1994, p. 4.
711. "Satellite Optical Products", advertising brochure issued by Wirin and Associates, Palm Springs, 1992.
712. C. Lardier, "La Russie Lance Un Mysterieux 'Cosmos'", Air & Cosmos, 26 August 1994, p. 53.
713. Technical documents provided by Space Liasion International Corporation offering TK-350 and KVR-1000 imagery products, 1993.
714. Sotsialisticheskaya Industriya, 17 September 1989, p. 4.
715. "CIS Satellites Displayed", Aviation Week and Space Technology, 26 June 1995, p. 51.
716. Nezavisimaya Gazeta, 10 June 1993, p. 6.
717. N. A. Armand and B. G. Kuzuza, "International Space Project of the Earth Remote Sensing 'Priroda'", Paper IAF-90-103, 41st Congress of the International Astronautical Federation, 1990.
718. "77 KSI Research Module, Purpose and Description", M. V. Khrunichev Machine Building Plant, 1989.

719. B. Z. Petrenko and S. V. Sokolovskiy, Issledovaniye Zemli Iz Kosmosa, March-April 1989, p. 123.
720. "77 KSO Optical Research Module, Purpose and Description", M. V. Khrunichev Machine Building Plant, 1989.
721. A. Lawler, "Environmental Satellite Plan Unveiled by Soviets", Space News, 22-28 October 1990, p. 27.
722. C. Lardier, "Les Nouveaux Projets de Lavotchkin", Air and Cosmos, 25 October 1992, p. 49-50.
723. "Tellura-EKO' Space Station", Salyut Design Bureau, Experimental Machine Building NPO, 1991.
724. "Salyut' Design Bureau of Experimental Engineering Industry NPO", undated prospectus for the Proton launch vehicle and three conceptual spacecraft.
725. V.I. Sapozhnikov, Novosti Kosmonavтики, 19 November - 2 December 1994, pp. 38-39.
726. Yonhop News Agency, Seoul, 10 August 1992 and 27 September 1993.
727. A. Lawler, "South Korea Plans To Build, Launch Satellites", Space News, 28 May-3 June 1990, pp. 1, 20.
728. R. Riccitiello, "Kitsat-A Launch Is First Step for Korean Space Program", Space News, 24-30 August 1992, p. 10.
729. "South Korea Set for Launch No. 2", Spaceflight, July 1993, p. 246.
730. W. Boyer, "TRW Wins Bid To Develop Korea Multipurpose Satellite", Space News, 19-25 September 1994, p. 8.
731. A. Yevtushenko, Poisk, 30 December 1993, p. 13.
732. Interfax News Agency, 20 September 1994.
733. ITAR-TASS News Agency, 24 January 1995.
734. UNIAN News Agency, 2 March 1995.
735. Y. Andreotti, Advances of Science and Technology, No. 21, 5 November 1985, pp. 1-5.
736. Information on Meteorological and other Environmental Satellites, op cit., p. V-17-V-22.
737. A. I. Kalmykov, et al, Determination of Oceanic Surface Structure with "Cosmos-1500" Satellite Side Looking Radar, Intercosmos Council, 1984.
738. M. V. Bukharov, et al, Issledovaniye Zemli Iz Kosmosa, May-June 1991, pp. 26-32.
739. A. I. Kalmykov, "Space-based Prediction of Catastrophes", NTR: Problemy I Resheniya, 1989, p. 3.

740. The "Yuzhnoye" Scientific-Production Association (NPO), Rocket-Space Research and Test Centre, Dnepropetrovsk, 1989.
741. Europe and Asia in Space 1991-1992, pp. 138-139.
742. P.B. de Selding, "ESA To Increase Parabolic Experiment Funding", Space News, 12-18 December 1994, p. 6.
743. Annual Report '93, ESA, May 1994, pp. 67-68.
744. European Space - On Course for the 21st Century, ESA BR-39, ESA, 1987.
745. Spacelab Data Book, ESA BR-14, ESA, 1983.
746. D. J. Shapland, "Spacelab and the Space Shuttle", The Cambridge Encyclopedia of Space, 1990, p. 278-283.
747. Annual Report '94, ESA, 1995, pp. 69-70.
748. J.T. McKenna, "Shuttle Flight To Aid Materials, Life Studies", Aviation Week and Space Technology, 4 July 1994, pp. 28-29.
749. Experiments in Space. The Second German Spacelab Mission D-2, DLR, March 1992.
750. EURECA, ESA BR-16, ESA, 1983.
751. J. R. Asker, "Eureca Will Offer New Capabilities for Extended Microgravity Experiments", Aviation Week and Space Technology, 20 July 1992, p. 46-47.
752. "ESA Rescues Eureca from Low Orbit, Tests Payloads for 9-month Flight", Aviation Week and Space Technology, 10 August 1992, p. 61.
753. W. Harwood, "ESA Prepares Eureca for Retrieval by Endeavor Crew", Space News, 24-30 May 1993, p. 9.
754. J.T. McKenna, "EURECA Hits Snags, Shuttle Launch Slips", Aviation Week and Space Technology, 31 May 1993, pp. 27-28.
755. W. Harwood, "Astronaut Unsticks Eureca Antennas", Space News, 28 June - 11 July 1993, p. 3.
756. R. Riccitiello, "ESA Budget May Exclude Eureca", Space News, 24-30 August 1992, p. 10.
757. P. B. de Selding, "Eureca Platform May Be Retired After Retrieval", Space News, 1-7 March 1993, p. 4.
758. "Microgravity Joint Project", Spaceflight, October 1994, p. 330.
759. P.B. de Selding, "French To Adapt Soviet Capsule for Western Clients", Space News, 11-18 November 1991, p. 17.
760. R. Riccitiello and P.B. de Selding, "Columbia To Carry European Payloads", Space News, 19-25 October 1992, p. 6.

761. "Microgravity Oven Takes Second Flight on Shuttle", Space News, 14-20 March 1994, p. 12.
762. "Information File", CNES, May 1992.
763. "Antares Press Kit", CNES, July 1992.
764. R. Schuiling, "Columbia Reaches '100th Day in Space': Shuttle Program Closes Up 'One Year in Space'", Spaceflight, July 1993, pp. 232-236.
765. M.H. Keller and P.R. Sahm, "The German Spacelab Mission D2: A Scientific Technological Challenge", Earth Space Review, Vol. 3, No. 1, 1994, pp. 11-21.
766. "Japan and Germany Plan Launch", Aviation Week and Space Technology, 18 January 1993, p. 13.
767. EXPRESS Space Vehicle, technical specification sheet distributed by Khrunichev State Space Research and Production Center, undated.
768. J.M. Lenorovitz, "Russian Capsule Role Complicates Joint Flight", Aviation Week and Space Technology, 16 August 1993, p. 71.
769. "Australia, Germany Form Space Ties; Woomera Range Activated", Space FAX Daily, 22 October 1993, p. 1.
770. C. Covault, "Space Programs Surge in Asia/Pacific Region", Aviation Week and Space Technology, 21 February 1994, pp. 73-75.
771. P.B. de Selding, "Express Misses Japan's Summer Launch Window", Space News, 19-25 September 1994, p. 4.
772. C. Covault, "German-Russian Projects Advance", Aviation Week and Space Technology, 14 November 1994, p. 24.
773. INTERFAX News Agency, 24 November 1994.
774. P.B. de Selding, "Australia Clears Russian - German Express for Landing", Space News, 9-15 January 1995, p. 18.
775. "Italy Bets on Bantonweight Carina", Space News, 9-15 July 1990, p. 2.
776. R. DeMeis, "Alenia", Aerospace America, November 1992, p. 10-11, 39.
777. T. Sienko, "Microgravity and Japan", Space, November-December 1990, pp. 36-40.
778. C. Covault, "First Japanese Shuttle Astronaut Set for 1991 Spacelab J Flight", Aviation Week and Space Technology, 27 August 1990, p. 72-75.
779. J. R. Asker, "U.S., Japan Ready Spacelab Flight", Aviation Week and Space Technology, 7 September 1992, p. 39.

780. "Outline of IML-2 Experiment Themes Experiment Using Large Isothermal Furnace (LIF)", NASDA Report, No. 24, Spring 1994, pp. 14-15.
781. "Mitsubishi To Reserve Room Aboard SpaceLab", Space News, 28 June - 11 July 1993, p. 2.
782. H-II Launch Vehicle No. 3, Press Kit, NASDA, February 1995.
783. "First Japan Reusable Spacecraft to Carry Science, Technology Payload", Aviation Week and Space Technology, 20 August 1990, p. 70-74.
784. "Japanese Panel Recommends Spaceplane Development", Aviation Week and Space Technology, 6 July 1987, p. 31.
785. "Japan Showcases Maturing Space Program, Manufacturing Capabilities", Aviation Week and Space Technology, 19 June 1989, p. 66-70.
786. S. W. Kandebo, "Japanese Refining Unmanned HOPE Orbiter for Planned 1996 Launch", Aviation Week and Space Technology, 3 April 1989, p. 57-58.
787. "Space Agency Considers Doubling Size of HOPE Unmanned Space Vehicle", Aviation Week and Space Technology, 13 August 1990, p. 65-68.
788. K. P. Dawson, "Japan's Space Plane Faces Termination or Shrinking", Space News, 23-29 November 1992, p. 3.
789. "China Would Lease Payload Space on Its Recoverable Satellites", Aerospace Daily, 25 February 1987, pp. 286-287.
790. Zhongguo Xinwen She News Agency, 26 March 1993.
791. Zhu Yilin, "Space Microgravity Scientific Experiments in China", Spaceflight, October 1993, pp. 334-335.
792. Principal Technical Characteristics of the Space Vehicle "Photon" and Specifications of its Scientific Instrumentation, GLAVKOSMOS, 1987.
793. G. P. Anshakov, et al, "Earth Resources and Research Automated Spacecraft", Photon Design Bureau, 1989.
794. Spacecrafts for the Production of Materials and Microgravity Experiments, Photon Design Bureau, GLAVKOSMOS, 1990.
795. Wide Experience in Developing of Space Technology, Photon Design Bureau, 1990.
796. "German Mirka Craft To Launch Aboard Russian Soyuz", Space News, 21 November - 4 December 1994, p. 17.
797. C. Lardier, "La Capsule Mirka Volera Avec Photon en 1996", Air & Cosmos, 18 November 1994, p. 39.



798. J. M. Lenorovitz, "Soviets Book New Commercial Payloads, Grant Greater Access to Space Facilities", Aviation Week and Space Technology, 9 October 1989, pp. 121-123.
799. "The Nika-T", GLAVKOSMOS, 1989.
800. Lavochkin, prospectus distributed by Lavochkin NPO, 1990.
801. Space Apparatus "Mercury", prospectus distributed by Lavochkin NPO, 1991.
802. P. Longereux, "Premier Satellite 'Lavochkine' en 1993", Air & Cosmos, 6 October 1990, p. 32.
803. Lavochkin Spacecraft, prospectus distributed by Lavochkin NPO, 1991.
804. C. Lardier, "Les Nouveaux Projets de Lavotchkine", Air & Cosmos, 25 October 1992, p. 49-50.
805. Izvestiya, 29 May 1992, p. 2.
806. Moskovskiye Novosti, 15 November 1992, p. 6.
807. Space Biotechnological Complex for Light Weight Spacecrafts, technical specifications distributed by Salyut Design Bureau, 1991.
808. Unified Space Platform, technical specifications brochure, Salyut Design Bureau, 1991.
809. Technologiya Spacecraft, technical specifications brochure, Salyut Design Bureau, 1991.
810. Pravda, 17 May 1990, p. 3.
811. "'Tellura-EKO' Space Station", Salyut Design Bureau, 1991.
812. Orbital Plant. Unique Materials and Preparations Production in Space Environment, Salyut Design Bureau, 1991.
813. Zemlya i Vselennaya, March-April 1992, p. 18-25.
814. Moscow Radio, 7 August 1990.



## 5.0 SPACE SCIENCE AND EXPLORATION PROGRAMS

Whereas the applications satellites described in the previous section provide essential support services with direct economic impact on national and international markets, space science and exploration programs, in particular those dedicated to life sciences, geophysics, astrophysics, and solar system exploration, enjoy greater notoriety. On the whole, science missions also represent the most costly undertakings with the exception of manned space flight. Consequently, in recent years a significant portion of such missions involves widespread international participation. This section focuses on unmanned, near-Earth and deep space probes, with brief descriptions of manned space science activities included with appropriate references to related summaries appearing in Section 3.

### 5.1 LIFE SCIENCES

The study of the effects of space travel on living organisms predated the launch of Sputnik 1 in 1957 through extensive high altitude ballistic flights conducted by the US and the USSR beginning shortly after World War II. Once orbital flights were possible, the range of life sciences experiments on all levels of biology and botany, from simple cells to man himself, quickly expanded. For more than 30 years the short-term and long-term effects of microgravity and radiation on the maintenance and reproduction of life in space have been the subject of intense scientific investigations by researchers around the world. To date, citizens from approximately three dozen nations have flown in space, and several European and Asian countries are currently pursuing significant life sciences space programs.

#### 5.1.1 European Space Agency

ESA has sponsored a variety of life sciences activities since its first such mission in 1985. These endeavors have been both in concert with other agencies, namely USSR/Russia and NASA, and as strictly European initiatives. Those missions entirely administered by ESA often have one member country or more as the principal participant or lead state. In some cases, the distinction between international and national programs may be somewhat blurred.

For example, the first major ESA life sciences experiments were the Biorack, Anthorack, and Vestibular Sled flown on Spacelab D1, which was primarily funded by Germany. Of the three European astronauts who flew on that mission, two were German and one was Dutch. While Germany is a strong participant in ESA, its two astronauts were official representatives of DARA on Spacelab D1. The Dutch astronaut was a representative for ESA (Section 5.1.3).

ESA was involved with the three most recent USSR/Russia Bion flights: Bion 8 in 1987, Bion 9 in 1989, and Bion 10 in 1992-3. Analysis of data from the Bion 8 and 9 missions reported the retarded development of germinating seeds and other botanical developmental processes. Bion 10, launched in late 1992, included the maiden flight of ESA's Biobox, a general-purpose incubator with a programmable temperature profile mounted on the exterior of the Bion reentry capsule with 10 life sciences experiments. Although no additional Bion missions were flown during 1993-1994, ESA took advantage of a flight opportunity on Photon 6 in 1994 to conduct six radiation biology experiments in Kayser-Threde GmbH's Biopan facility (Reference 1).

Another major life sciences project for ESA was Spacelab IML-1. ESA astronaut Ulf Merbold, along with one Canadian and five American astronauts, manned the International Microgravity Laboratory during 22-30 January 1992. ESA provided two main life sciences facilities for the mission: Biorack and the Vestibular Sled. Both platforms had been used previously on Spacelab D1. Biorack, shown in Figure 5.1, is a general purpose facility for the study of cellular and developmental processes in plants and animals. Aboard IML-1, 17 life sciences experiments were fielded, including insects, bacteria, animal tissue, frog eggs, molds, yeasts, and several plants. The Vestibular Sled is a track-mounted chair that is used to test human nervous system responses to a variety of accelerations in weightlessness. Biorack was flown for a third time on IML-2 in July, 1994.

The previous year ESA's Anthorack, designed to evaluate adaptation to low gravity by the human body, was successfully flown on Spacelab D2. Additional life sciences data were

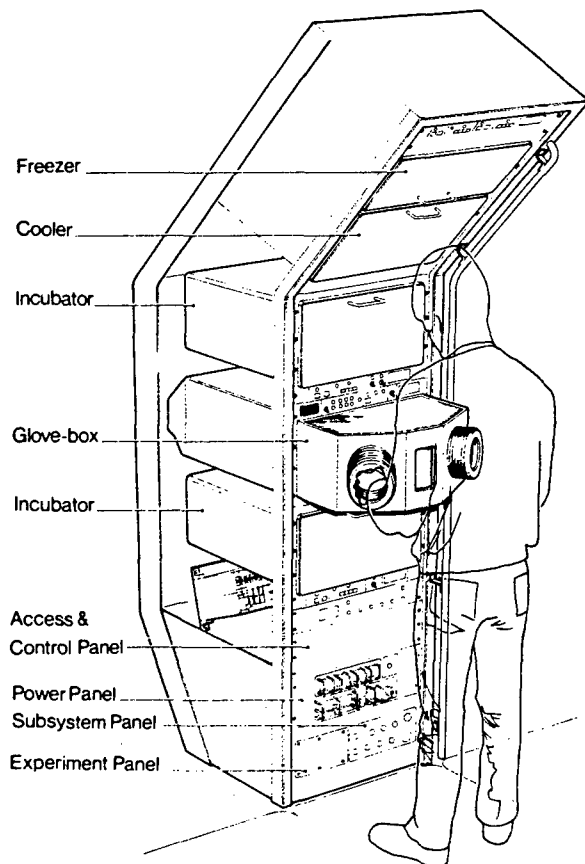


FIGURE 5.1 ESA'S BIORACK.

collected during the flights of STS-61 and STS-66 which carried ESA astronauts Nicollier and Clervoy, respectively. ESA's most extensive manned life sciences program was conducted under the Euromir 94 project when ESA astronaut Merbold spent 29 days on-board the Russian Mir space station performing 15 physiology experiments (Section 3.6).

Another ESA life sciences project was carried aboard the European Retrievable Carrier (EURECA). Launched 31 July 1992, EURECA operated at an altitude of 500 km with an orbital inclination of 28.5° and was designed for longer-duration experiments than are available with Spacelab. After eleven months in orbit, the US STS retrieved EURECA in June, 1993. Used for both materials and life sciences, EURECA's first mission included the Exobiology and Radiation Assembly as one of the five major components of the payload. EURECA-1 utilized about seventy percent of the maximum 1,000-kg payload capacity (Figure 5.2). Optimal

microgravity conditions are about  $5 \times 10^{-7}$  g (an order of magnitude better than is achievable aboard Spacelab), while the guaranteed worst conditions are  $10^{-5}$  g (similar to Spacelab). Originally planned for five flights, future missions of EURECA are uncertain (References 2-4).

ESA plans to continue its life sciences experiments on Russian (Mir, Photon, and Bion) and American (STS) spacecraft while preparing for its role in the International Space Station program with emphasis on its own Columbus Orbital Facility. ESA's Microgravity Advisory Committee in 1994 defined 15 high priority research areas in life sciences for future investigations.

#### 5.1.2 France

The majority of France's life sciences research has been conducted by French astronauts during four missions to Soviet/Russian space stations and one flight on board the US Space Shuttle. (A second mission on STS by J.F. Clervoy in 1994 was under the auspices of ESA.) The 2-week flight by M. Tognini and the 3-week flight by J.P. Haignere to the Mir space station in 1992 and 1993, respectively, permitted detailed experiments spanning the pre-flight, on-orbit, and post-flight phases with emphases on the effects of space flight on the human cardio-vascular system, blood composition changes, immunological responses to weightlessness, and the psychological and physiological condition of space travelers during adaptation to weightlessness. French astronauts are scheduled for further stays on-board Mir: C. Andre-Deshays in 1996 and L. Eyharts in 1997 (see Section 3.2 for details).

The French firm Matra Marconi employed a Chinese vehicle to carry a biological package in 1987. The payload was piggybacked on a Chinese FSW mapping satellite launched by a CZ-2C booster on 5 August 1987 from Jiuquan. Orbital characteristics were an altitude range of 173-400 km at a 63.0° inclination. The payload, which included algae, cyanophyta, and protozoa, was recovered 10 August 1987 and the sealed capsule was handed over to Matra Marconi on 12 August (References 5-6).

France led the development of ESA's Biorack and Anthrorack facilities which have flown on the US Space Shuttle and has been a contributor to all Soviet/Russian Bion missions since 1975 (Bion 3). Future French life sciences

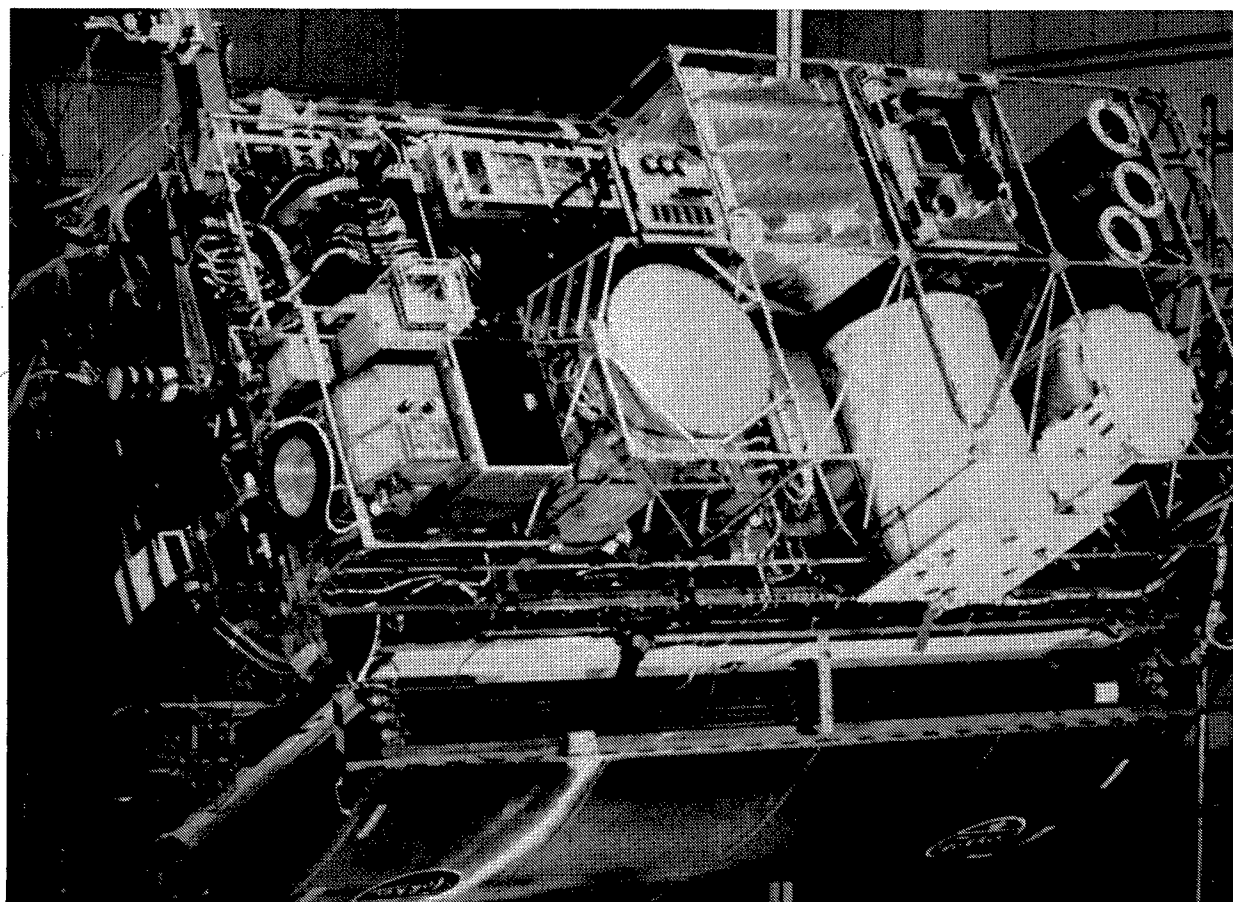


FIGURE 5.2 EURECA BEING PREPARED FOR FLIGHT.

experiments are likely to remain concentrated on manned rather than unmanned missions.

### 5.1.3 Germany

Germany has sponsored more astronaut missions than its continental European neighbors (six, including the flight of an East German astronaut in 1978) at the same time providing Ulf Merbold for three ESA flights. The Spacelab D1 (1985) and the Spacelab D2 (1993) missions on the US Space Shuttle completed a host of life sciences experiments as did the shorter flight of K.D. Flade on the Mir space station in 1992. German firms are also leading many European unmanned life sciences investigations.

Germany's first Spacelab mission was D1, a seven-day mission launched 30 October 1985. This mission marked the first time the scientific and technical control of the Spacelab was performed outside the US. The German Space Operations Center (GSOC) in Oberpfaffenhofen planned, prepared, and controlled D1. Two German payload specialists, Ernst

Messerschmid and Reinhard Furrer, worked in shifts with NASA and Dutch astronauts to provide nearly 24 hours per day access to the scientific payload. The manifest of German life sciences experiments included cellular biological, botanical, and medical experiments, utilizing ESA's Biorack, Anthrorack, and Vestibular Sled facilities (References 7-8).

Spacelab D2 (26 April - 6 May 1993) conducted life sciences experiments in four general areas: biological techniques (electrofusion of cells), biology (cell functions, reaction to gravity, development processes, and behavioral physiology), human physiology (heart-lung system, lung functions, endocrinology, and metabolism), and radiation physics. Of the five double-racks on board Spacelab D2, one was Germany's Bilabor for cell, botany, and zoological experiments, and one was ESA's Anthrorack (Section 5.1.1). As with Spacelab D1, Spacelab D2 was controlled by a payload team at GSOC (References 9-11).

Germany also provided national life sciences experiments for IML-1 and IML-2. Radia-

tion and gravitational sensitivity effects were studied on both missions while IML-1 also investigated cell cultivation and bioprocessing. Specific experiments on IML-2 included DARA's Slow Rotating Centrifuge Microscope and DLR's Biostack. The German COSIMA (Crystallization of Organic Substances in Microgravity Application) experiments have flown on both Chinese FSW and Russian Resurs-F recoverable capsules. Meanwhile, DLR's EXPRESS and Kayser-Threde's Biopan facilities are designed to make microgravity research, including life sciences, more affordable and more available.

#### **5.1.4 Japan**

The first Japanese life sciences experiment in space took place in late 1990, when Toyohiro Akiyama, a journalist from the Tokyo Broadcasting System, boarded the Mir space station. This was the result of a private Japanese company negotiating with GLAVKOSMOS and Energiya NPO and had no official sponsorship by the Japanese government or space agency. While on Mir, Akiyama performed several experiments on six Japanese Tree Frogs, gauging their adaptation to weightlessness (Reference 12).

Japan's space agency NASDA fielded its first major orbital life sciences experiment with the assistance of the US Space Shuttle program. Spacelab J, launched 12 September 1992 for an eight-day mission, included NASDA payload specialist Mamoru Mohri, NASDA's first astronaut. The Japanese experiment docket was also known as FMPT, First Materials Processing Test. The mission, which also hosted several materials science experiments, included biological investigations with live insects, frogs, chicken embryos, and fish. Biologists were encouraged by the first successful effort to fertilize frog eggs in weightlessness (References 13-14).

A reusable free-flying platform called the Space Flier Unit (SFU) has been scheduled to be launched aboard the third flight of Japan's new H-II launch vehicle, but development problems with the new booster pushed the launch of the SFU into 1995. SFU-1 is intended primarily for advanced technology and materials processing, but some biological experiments are expected to be fielded, including one (Space Biology Experiment) dealing with the growth of newts from egg to adult. After several months in space, the SFU is to be retrieved by the US

Space Shuttle. The SFU is a 3,500-kg craft with a 4.6 m diameter and two 9.6 m solar arrays. The effort is a joint project of NASDA, the Institute of Space and Astronautical Science (ISAS) and the Ministry of International Trade and Industry (MITI) (References 15-17).

Japan had some involvement in the numerous life sciences experiments aboard the 1992 Spacelab IML-1. Japan's major contribution to the mission was the Organic Crystal Growth Facility. On IML-2 Japan was responsible for the Thermoelectric Incubator/Cell Culture Kit, the Free-Flow Electrophoresis Unit, the Aquatic Animal Experiment Unit, and the Realtime Radiation Monitoring Device.

By far the largest orbital life sciences project underway in Japan is the major module for the International Space Station, JEM (Japanese Experiment Module). A consortium of 14 Japanese companies have formed Japan Manned Systems Corporation to coordinate construction of the shuttle-deployed module. JEM will be configured to allow a broad range of materials, observational, and life sciences studies. Construction of a working prototype of JEM was begun in 1992 for configuration testing and training. JEM is now scheduled for launch in two segments by the US STS in the year 2000.

The proposed layout of JEM consists of three main modules (Section 3.4). The Pressurized Module (10 m long, 4 m diameter, 10,250 kg) contains numerous experiment racks and controls for JEM. The Experiments Logistics Module (4 m high, 4 m diameter, 2,450 kg), which is located above the Pressurized Module, is largely a storage and transport module for replenishing perishable items used for JEM. An exposed rack can be mounted on the Experiments Logistics Module to facilitate equipment and resupply cargo shuffling. The Exposed Facility consists of two external pallets (each 2.5 m high, 1.4 m wide, 4 m long) with a total mass of 2.8 metric tons and a manipulator arm for servicing the exposed experiments without EVA. Expected power requirements are 6 to 9 kW, depending on mission parameters.

#### **5.1.5 People's Republic of China**

Similar to early experiments by the USSR, PRC launched animals, including dogs and mice, on suborbital flights in the mid 1960s. Early Chinese efforts focused mainly on unmanned military and civilian space applications, thus life sciences experiments were few. In the 1980's the Great Wall Industries Corpora-

tion began promoting commercial applications of the Chinese space program, including the opportunity to fly small life sciences payloads on board the FSW recoverable spacecraft which had been developed as an observation platform (Section 4.3.9). The first Western payload was launched 5 August 1987 for the French aerospace company Matra Marconi and was a biological microgravity experiment (Section 5.1.2) (References 18-19).

A Chinese biosatellite, FSW-1 3, was launched 5 October 1990 from Jiuquan. Sixty animals and plants were included on the mission, including rats and guinea pigs. Primary studies focused on the effects of weightlessness on metabolism, food requirements, and excretion. The experiments and biosystems were developed by the Astronautical Engineering Institute of the State Commission of Science, Technology, and Industry for National Defense. The recoverable capsule was returned to Earth eight days after launch. The mission initial altitude was 208-311 km at an inclination of 57.0° (References 20-23).

China's Institute of Hydrobiology fielded a group of experiments on FSW-1 4, launched from Jiuquan 6 October 1992. The biosatellite payload included algae, microorganism, rotifers, and a small aquatic creature. Dr. Liu Yongding, Institute Deputy Director, said that the algae experiments were particularly successful, with one new form of blue algae produced. The Chinese are considering algae as a potential food source for astronauts on long space missions. The FSW-1 was deployed in an orbit at 213-309 km altitude with an inclination of 63.0° (Reference 24). Future Chinese life sciences experiments may be flown on the more capable FSW-2 which was introduced in 1992.

#### 5.1.6 Russian Federation

The USSR was the first space-faring power, and, not surprisingly, orbited the world's first biosatellite. Sputnik 2, launched less than a month after its world-shocking predecessor, contained a female dog named Laika in an instrumented and pressurized chamber. Launched 3 November 1957, Sputnik 2 returned biological, movement, and sound data on Laika until the environmental control system could no longer sustain her. Fourteen dogs and one rabbit had previously been launched during Soviet vertical rocket tests, and numerous dogs and other small animals and insects were later

orbited during the early years of the Soviet space program (Reference 25).

The largest effort in the life sciences on the part of the Russian Federation is the Bion, or Biokosmos, program, managed by the Institute of Biomedical Problems in Moscow. Bion is an ongoing program that has orbited ten satellites since 1973. Unlike Sputnik 2, all Bion satellites have been recovered after reentry, though some minor casualties have occurred in the program. Participation in Bion is truly international, with countries other than the former Soviet Union participating in all but the first mission and with the US participating in the eight missions since 1975.

All Bion missions have used a modified Vostok recoverable capsule as shown in Figure 5.3. This vehicle is a derivative of the spacecraft used by Yuri Gagarin on his historic orbital flight in 1961. Similar Vostok-derived craft still in use include the Photon microgravity/materials research satellites and the Resurs-F Earth environment/resource monitoring systems, produced by the Samara Specialized Design Bureau. The Bion experiment (reentry) chamber is a 2.3 m diameter sphere with two 1.2 m access hatches. The scientific payload is about 1,000 kg, while the overall spacecraft mass is about six metric tons. All Bion missions have been launched by Soyuz launch vehicles from the Plesetsk Cosmodrome (Reference 26).

Throughout the history of the Bion program, several notable and sometimes humorous incidents have occurred. The mission of Bion 3 (Kosmos 782) was cut short because of threatening snowstorms in the intended satellite recovery area. Soviet scientists reported "wintry" conditions during recovery and were forced to erect shelters at the landing site. Yerosha, one of the monkeys on Bion 8 (Kosmos 1887) partially freed himself and explored his orbital cage, much to mission controllers' dismay and the popular media's delight. On reentry, Bion 8 then missed its intended touchdown point by about 3,000 km, causing the demise of several fish in frigid weather. Bion 9 (Kosmos 2044) experienced temperature control problems three days before reentry, killing some ants and earthworms that were part of a school project (References 27-32).

The Bion 10 satellite (Kosmos 2229), launched 29 December 1992, was scheduled to orbit for 14 days before reentry and recovery, but thermal control problems sent onboard tem-

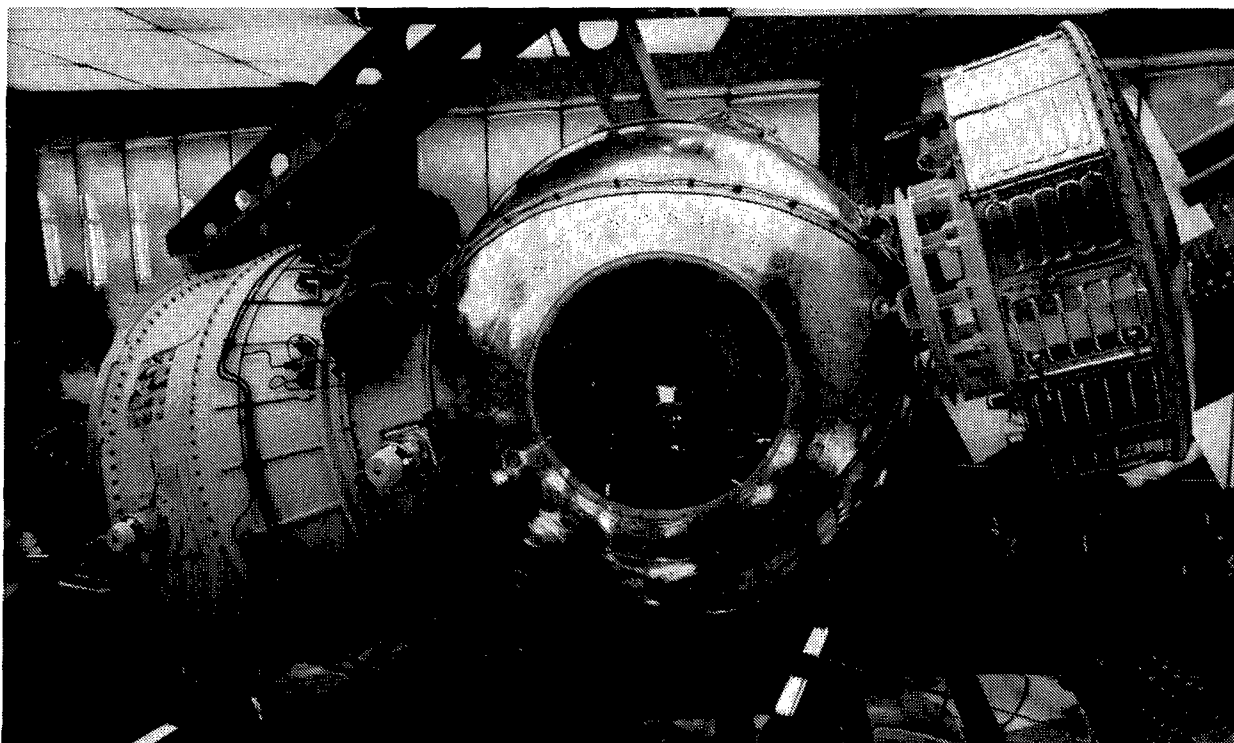


FIGURE 5.3 BION SATELLITE.

peratures to unacceptable levels, and the craft was deorbited two days early on 10 January 1993. This forced Russian officials to land the spacecraft near the Kazakh town of Karaganda, rather than the planned location near Kustanay. The high on-board temperatures are suspected of killing seven of the fifteen tadpoles. Additionally, one of the two monkeys on board went without food for three days, suffering measurable weight loss. After treatment for dehydration, both monkeys (Krosh and Ivasha) were declared healthy. Yevegeniy Ilyin, a scientist at the Institute of Biomedical Problems, declared that, in spite of the equipment problems, the experiments were "generally successful" (References 33-36).

Although Bion 11, which was being prepared in late 1994, will employ the standard Vostok-derived platform, future biosatellite missions may adopt the more capable NIKA spacecraft bus now under development. NIKA will offer longer mission durations, increased recoverable payload (up to 1,200 kg), and greater power generation capabilities. The new biosatellite variant being designed by the Photon Design Bureau has been designated NIKA-B, Scientific Research Spacecraft - Biological (References 26, 37-39).

The Russian man-in-space program represents the world's foremost life sciences programs in general biology, human physiology, zoology, and botany. A myriad of both simple and complex life sciences experiments have been conducted on a regular basis since the introduction of manned space stations in 1971. The permanently manned Mir space station has been the site of many pioneering life sciences experiments, albeit not all have been successful. Perhaps the most important experiment to date was the more than 14-month flight of Dr. V. Polyakov on board the orbital station. This and other life sciences experiments are described more fully under manned flight operations (Section 3.6).

#### 5.1.7 Ukraine

By the end of 1994, Ukraine was still waiting to launch its first national satellite, Sich 1, for the purpose of Earth observation and remote sensing. However, in mid-1994 a report claimed that the Yuzhnoye Design Bureau in Dnepropetrovsk intended to launch a biosatellite during 1996-1997. No specifications about the payload, the spacecraft or the launch vehicle were forthcoming (Reference 40).



## 5.2 GEOPHYSICS

The missions discussed in this section detail Eurasian efforts to characterize the Earth's geomagnetic environment in terms of radiation belts and interactions with the solar wind as well as the small particulate environment in near-Earth space. In recent years, a loose international alliance of scientists has been formed to share and distribute the results of numerous independent missions. The International Solar Terrestrial Physics (ISTP) program is a multinational effort whose 1977 origin was prompted by the Inter-Agency Consultative Group (IACG). ISTP now consists of over 100 entities (mostly universities and other research facilities) in many countries.

### 5.2.1 Czech Republic

For nearly 20 years the Geophysics Institute (renamed the Institute of Atmospheric Physics in 1994) in Prague has specialized in the development of very small, scientific satellites designed to investigate the complex nature of the Earth's magnetosphere and ionosphere. In many ways, these satellites were the forerunners of the now popular microsatellites. Although the size and mass of the Czech Magion satellites are similar to the more recent platforms produced by the UK's University of Surrey, Magion satellites are highly sophisticated spacecraft designed for state-of-the-art geophysics exploration.

Developed under the former Interkosmos program, Magion satellites are launched as piggyback spacecraft designed to carry out their experiments in concert with a mother satellite. Magion 1 with a mass of only 15 kg was launched with Interkosmos 18 in 1978 to monitor low frequency propagation in LEO from an initial orbit of only 400 km by 775 km with a high inclination of 83°. Magion 2 appeared in 1989 with Interkosmos 24 under the Aktivnyy project to investigate VLF propagations in the magnetosphere and their interaction with energetic particles in the Earth's radiation belts in an orbit of 505 km by 2,490 km with an inclination of 83°. Magion 2 (Figure 5.4) also introduced the current Magion base configuration with a mass of approximately 50 kg and a diameter of 0.6 m. The octagonal bus is equipped with four small solar arrays as well as body-mounted solar panels. Magion 2 also carried a Soviet Pulsar maneuvering system to regulate the distance between the sub-satellite and its companion

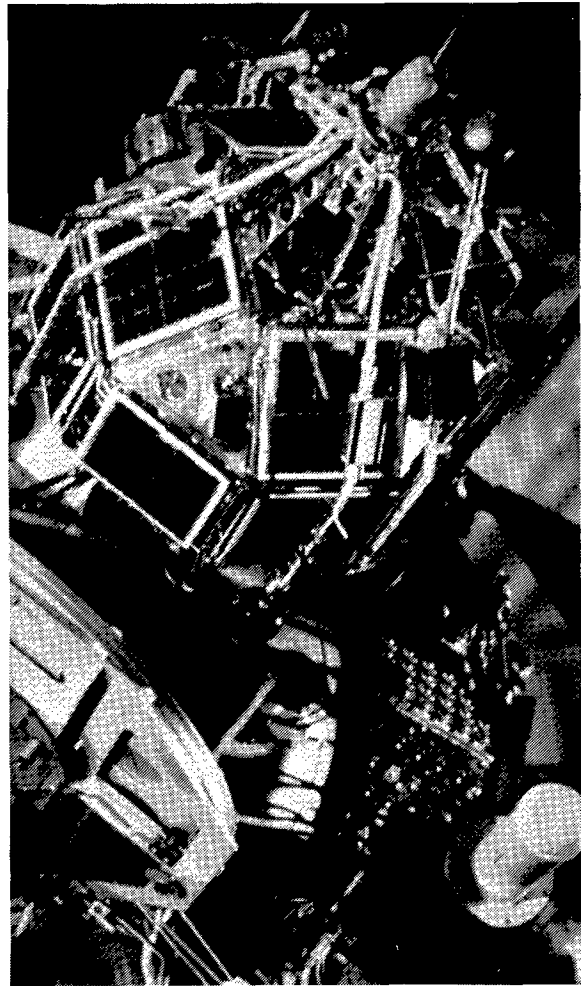


FIGURE 5.4 MAGION-2 SUB-SATELLITE.

spacecraft, although on this mission the system malfunctioned.

Magion 3 continued the work begun by its predecessor after launch in 1991 with Interkosmos 25 under the APEKS (Active Plasma Experiment) program. Essentially identical to Magion 2, Magion 3 recorded the effects in the magnetosphere of electron and Xenon ion beams injected by Interkosmos 25. The Pulsar engine performed well on this mission which lasted nine months in an orbit of 440 km by 3,070 km with an inclination of 83°.

Two more Magion spacecraft are being prepared in conjunction with the Interbol project which will employ two pairs of spacecraft (mother-daughter) to investigate the magnetospheric tail and auroral zones, respectively. After several years of delays Magion 4 is expected to be launched in 1995 with a Russian Prognoz M2-class spacecraft and inserted into an orbit of approximately 500 km by 200,000

km. Magion 5 should follow 6-12 months later with another Prognost M2 spacecraft in an orbit of 500 km by 20,000 km. The masses of Magion 4 and 5 are expected to be slightly heavier than earlier models, i.e., approximately 60 kg. Additional details of the Interbol program are provided in Section 5.2.7 under the Russian Federation subsection.

### 5.2.2 European Space Agency

After a quarter century of successful investigations with HEOS (Highly Eccentric Orbit Satellite) 1 and 2, GEOS (Geostationary Satellite), and ISEE (International Sun-Earth Explorer) 2, ESA's principal geophysics mission of the 1990's is the Cluster project, part of the first cornerstone of the Horizon 2000 program called the Solar/Terrestrial Science Program (STSP). Adopted in 1985, STSP includes both Cluster and the Solar and Heliospheric Observatory (SOHO, Section 5.3.1). As its name implies, Cluster consists of four identical, independent spacecraft which will study the physical interaction between the Sun and the Earth, specifically, boundary region physics, plasma acceler-

ation in the geomagnetic tail, plasma sheet turbulence, vortices and eddies, bow shock structure, and plasma and field microstructure (Figure 5.5). All four spacecraft are scheduled for launch on the maiden flight of Ariane 5 in 1995-1996.

Each spacecraft with a mass of 1,200 kg (54% propellant), a diameter of 2.9 m, and a height of 1.3 m will be deployed into a 90° polar orbit with a perigee of 25,513 km (4 Earth radii) and an apogee of 140,318 km (22 Earth radii). The spacecraft will fly in a tetrahedral formation with intersatellite distances ranging from 200 km in the cusp to 20,000 km in the magnetotail. Body-mounted solar cells will generate 224 W to support a design life of two years for the spin-stabilized (15 rpm) spacecraft.

The 72-kg Cluster scientific payload includes eleven main instruments: Spatio-Temporal Analysis of Field Fluctuations (STAFF), Electric Fields and Waves (EFW), Waves of High Frequency and Sounder for Probing of Density by Relaxation (WHISPER), Wide Band Data (WBD), Digital Wave Processor (DWP), Fluxgate Magnetometer (FGM), Electronic Drift

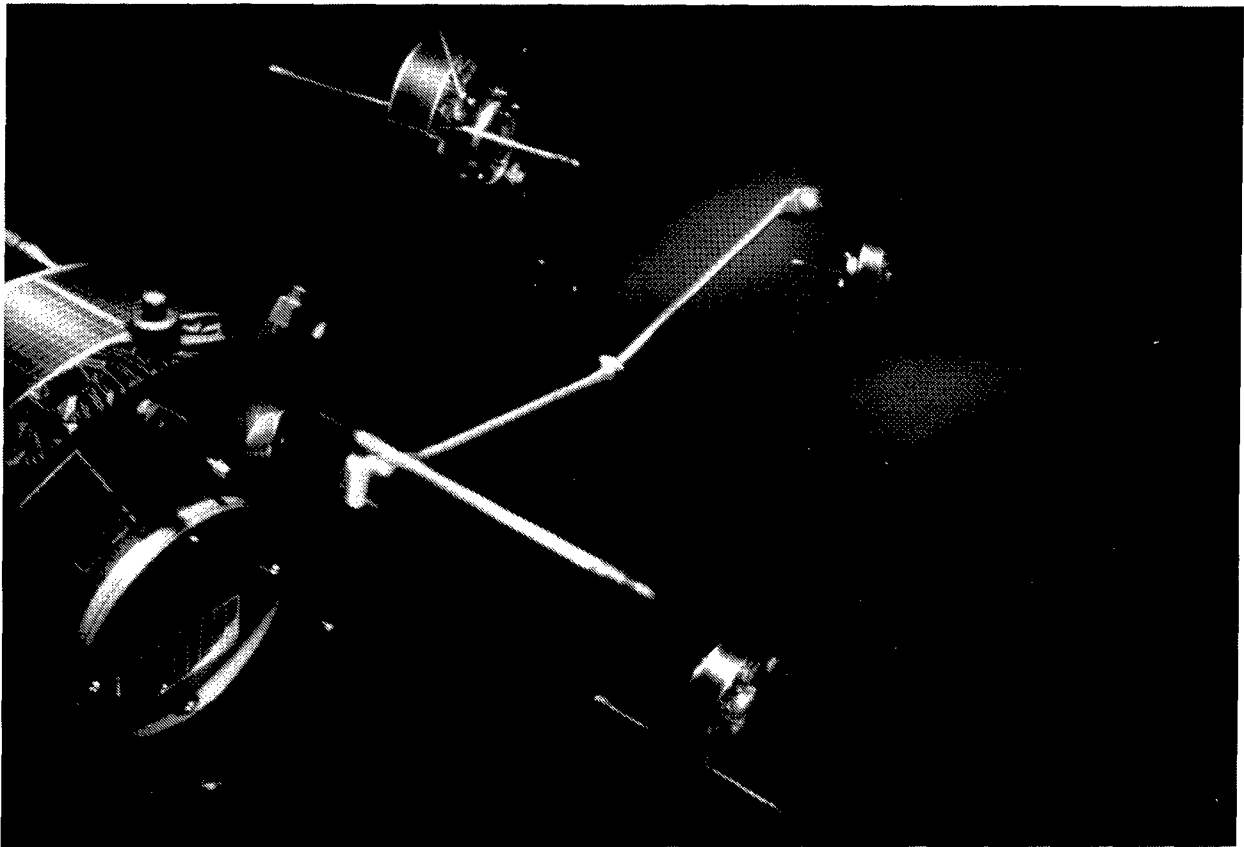
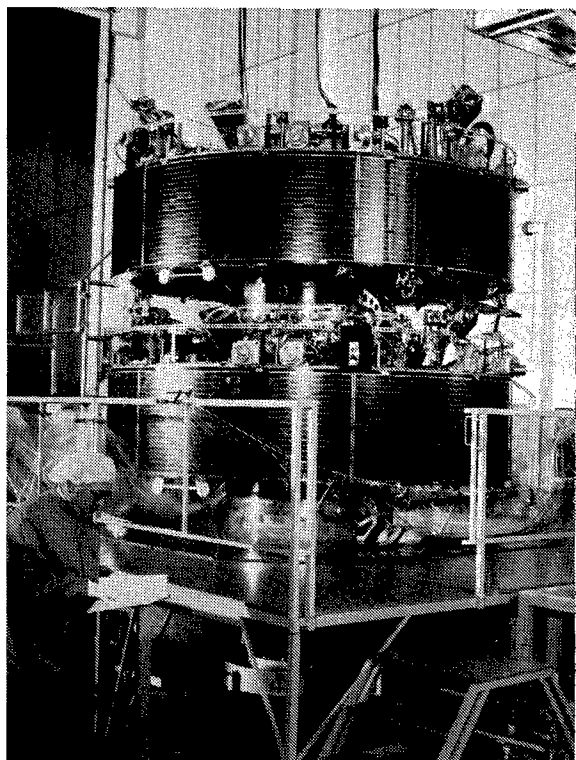


FIGURE 5.5 QUARTET OF CLUSTER SATELLITES.



**FIGURE 5.6 PAIR OF CLUSTER SATELLITES UNDERGOING VIBRATION TESTING.**

Instrument (EDI), Cluster Ion Spectrometry (CIS), Plasma Electron and Current Analyzer (PEACE), Research with Adaptive Particle Imaging Detectors (RAPID), and Active Spacecraft Potential Control (ASPOC). Figure 5.6 depicts two Cluster spacecraft undergoing vibration testing in Ottobrun, Germany. Dornier is the prime contractor for Cluster with Alcatel, British Aerospace (now Matra Marconi), DASA, Fokker, and Contraves as major subcontractors (References 41-47).

### **5.2.3 Germany**

Ten years after its last geophysics satellite project with the US and the UK (AMPTE, 1984), Germany returned to the field with a small free-flying satellite deployed by the US Space Shuttle. The University of Bremen, with the financial support of DARA and the Federal Ministry of Research and Technology, developed the 63-kg micro-satellite named Bremsat to conduct a variety of experiments, including an analysis of the flux of tiny micrometeoroids and space debris in very low Earth orbits. The 0.5-m diameter dodecahedron carried a useful payload of nearly 50% of the total spacecraft mass.

Released at an altitude of approximately 350 km by STS-60 on 9 February 1994, the spacecraft performed exceptionally well until its reentry into the Earth's atmosphere almost exactly one year later. Particles as small as 10-15 g were detectable by the sensitive impact counter (Reference 48).

In conjunction with ISTP, Germany plans to launch the 240-kg Equator-S spacecraft on a mission to measure atomic particles and electromagnetic fields in a nearly equatorial plane. After insertion into a GTO in 1997 as an Ariane piggyback payload, Equator-S will use a solid-propellant motor to raise its apogee to approximately 70,000 km. The Max Planck Institute will manage the mission which will also carry ESA and US scientific instruments (Reference 49).

### **5.2.4 Italy**

Although Italy's primary involvement in geophysics experiments is via ESA, a major national project undertaken in conjunction with the US is the Tethered Satellite System (TSS). Designed for deployment by the US Space Shuttle, TSS is a 520-kg, 1.6-m diameter satellite equipped with 70 kg of instruments to evaluate the upper atmosphere and geomagnetic field at the end of a 20-km-long, 2.5-mm-diameter Kevlar tether. The first flight of TSS, developed by Alenia Spazio, was on STS-49 in July-August, 1992. Unfortunately, deployment difficulties occurred almost immediately and the TSS tether was extended only about 250 m, when a protruding bolt in the Martin Marietta deployment mechanism jammed the device. The aborted experiment, however, did indicate that the satellite should be controllable via orbiter maneuvers. In addition to the standard geophysics experiments, the TSS should demonstrate several potential utilities for tethered satellites, including electrical power generation. The TSS alone may generate up to 5,000 volts as the tether passes through the geomagnetic field. A reflight of TSS is scheduled for early 1996 (References 50-55).

Alenia Spazio is also designing a small, free-flyer platform which could be used for geophysics experiments. One mission under consideration is the Central European Satellite for Advanced Research (CESAR) which would investigate the magnetosphere, ionosphere, and thermosphere. Envisioned as a nearly 300-kg platform, the satellite would be placed in an

elliptical orbit of 400 km by 1,000 km (Reference 56).

### 5.2.5 Japan

During 1993-1994 Japan continued to operate two spacecraft in Earth orbit dedicated to investigations of space plasma physics. EXOS-D (aka Akebono) was launched on 21 February 1989 by ISAS on a M-3SII booster into an elliptical orbit of 275 km by 10,475 km at an inclination of 75°. Designed to make measurements of the Earth's electromagnetic fields, plasma, and waves while imaging the aurora, the 295-kg, spin-stabilized EXOS-D has "revealed how the configuration of the aurora is related to the bulk flow of plasma across the geomagnetic field and how the activity of the magnetosphere is controlled by the magnetic field in interplanetary space" (Reference 57). By 1 January 1995 the orbit of EXOS-D had decayed to 270 km by 8,400 km.

Joining EXOS-D in July, 1992, was the Geotail satellite, a joint US-Japanese endeavor to probe the Earth's geomagnetic tail with emphasis on magnetic and electric fields,

plasma, and energetic particles. The 1,008-kg Geotail (Figure 5.7) was placed into a highly eccentric Earth orbit by a Delta-2/PAM-D combination with an apogee of approximately 350,000 km. Lunar gravitational perturbations were then used to gradually alter the orbit to nearly 1.3 million km apogee by 1994. Spacecraft propulsion later lowered the apogee to about 320,000 km toward the end of 1994 with further apogee reductions planned for 1995. The diameter and height of Geotail are 2.2 m and 1.6 m respectively, but two 6-m-long, magnetometer-equipped masts were deployed after launch as were two 50-m-long wire antennas designed to measure electric fields and waves. The design life of Geotail is approximately four years (References 58-60).

Meanwhile, Japan's 1985 Sakigake heliocentric satellite continues to return data on the solar system medium and the Earth's magnetosphere (Section 5.3.4).

### 5.2.6 People's Republic of China

Geophysics research on satellites has not been given many opportunities by PRC officials.

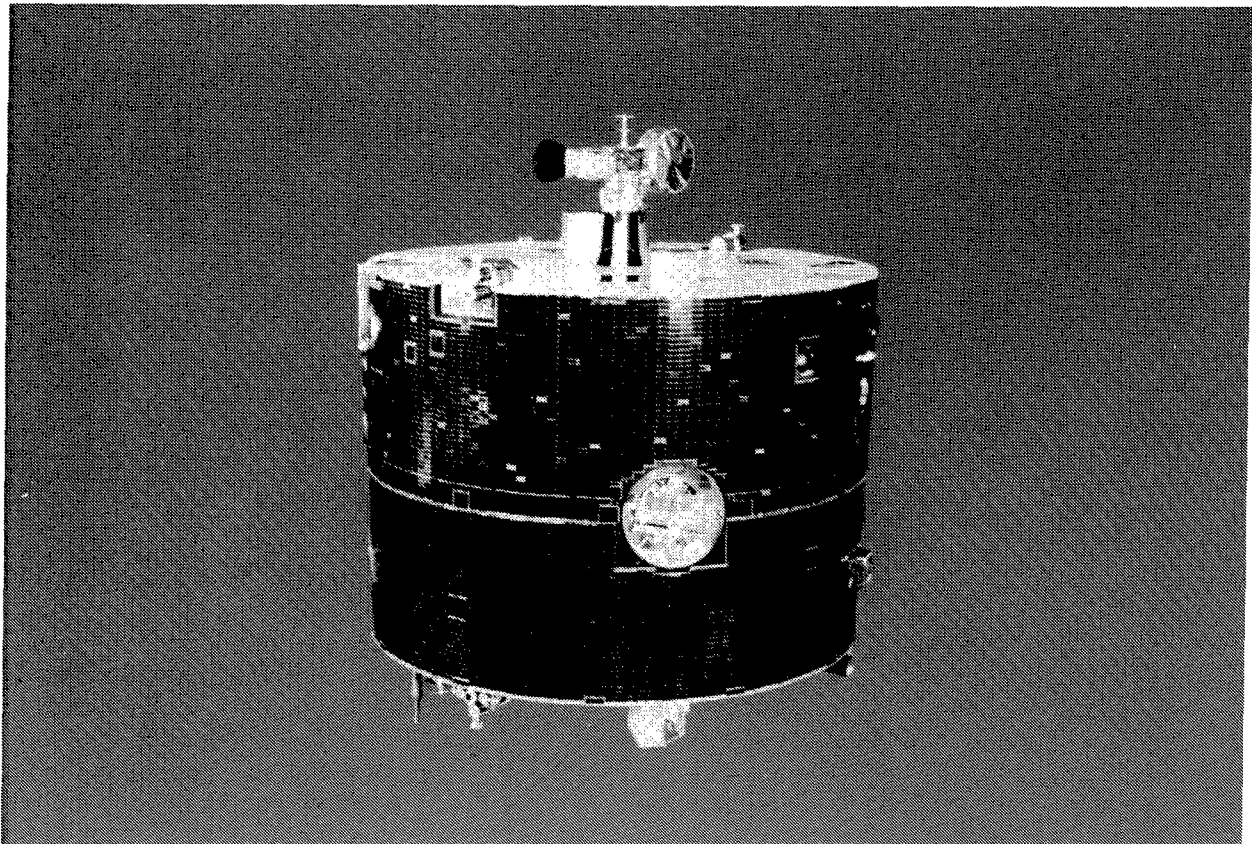


FIGURE 5.7 GEOTAIL SATELLITE WITH SENSORS STOWED.

The first notable experiments in the field were conducted by the Shijian-2 satellite in 1981 when charged particle detectors were included in the multi-discipline scientific payload. The initial 235 km by 1,600 km orbit limited the data collection period to less than one year.

Chinese scientists did take advantage of the first test flight of the CZ-3A launch vehicle on 8 February 1994 to deploy the 400-kg Shijian-4 spacecraft. Placed into a GTO of 212 km by 36,092 km with an inclination of 28.6°, Shijian-4 carried proton and electron detectors and a single event upset (SEU) monitor to return geophysical data. The spacecraft was spin-stabilized (10-20 rpm) and employed conventional, body-mounted silicon solar cells and NiCd batteries for the electrical power system (Reference 61).

### 5.2.7 Russian Federation

The USSR/CIS has conducted an active program for geophysics research since the launch of the Elektron spacecraft in 1964 for the study of the Van Allen radiation belts. The two most recent missions with major contributions from (then) Czechoslovakia were Aktivnyy (Interkosmos 24) in 1989 and APEKS (Interkosmos 25) in 1991 (Reference 62). Perhaps the most ambitious geophysics mission is Interbol, now expected to be launched in 1995 after many years delay. Other geophysics missions have been proposed, but fiscal constraints may lead to their cancellation.

The Interbol project, originally developed under the auspices of Interkosmos and planned for launch in the late 1980's, is similar in character to ESA's Cluster with four carefully coordinated spacecraft taking precise measurements of different portions of the magnetosphere. However, the techniques employed are somewhat different. The Interbol constellation will consist of two pairs of spacecraft: one pair with orbits of approximately 500 km by 200,000 km (tail probes) and one pair with orbits of approximately 500 km by 20,000 km (auroral probes). Both pairs will use 65° inclination orbits and will be launched 6-12 months apart by Molniya boosters from the Plesetsk Cosmodrome.

Each pair of spacecraft will consist of a Russian Prognoz M2 class spacecraft and a Czech Magion spacecraft with masses of approximately 1,250 kg (1,400 kg for auroral probe) and 50 kg, respectively. The Prognoz M2 spacecraft (Figure 5.8) is the latest model of the

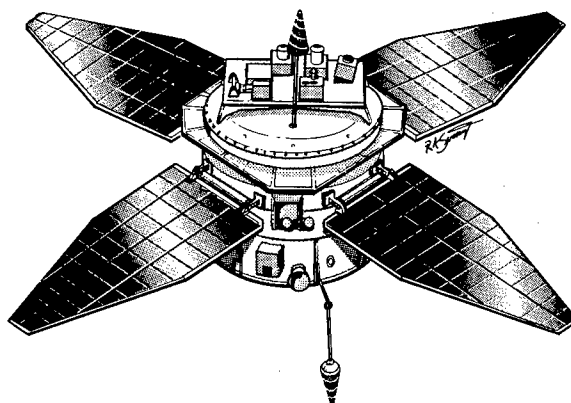


FIGURE 5.8 PROGNOZ-M2 SATELLITE.

Prognoz geophysical satellites introduced in 1972. Prognoz satellites have pioneered the use of extremely elliptical, 4-day orbits with apogees more than halfway to the Moon. (Prognoz 9 used an even longer 27-day orbit with an apogee of 720,000 km.) The Prognoz M2 spacecraft, with a payload capacity of 250-350 kg, will be spin-stabilized with a main-body diameter of 2.3 m and a height of 5.0 m. With deployed antennas the vehicle will span 12.5 m by 22 m by 22 m. Four solar panels will produce up to 250 W for the scientific payload from a total output of 900 W. Both probes will carry a variety of plasma and charged particle detectors. Swedish, French, and Canadian instruments will also be on board. The Magion sub-satellites will fly in close proximity to the Prognoz spacecraft but will be able to maneuver to as much as 10,000 km from the mother craft (Section 5.2.1) (References 63-66).

The very high orbit of Prognoz 9 (above) launched in 1983, was necessary to conduct the Relikt-1 experiment to examine the uniformity of the cosmic 2.7°K black-body radiation which is believed to represent the remnant of the creation of the universe according to the big-bang theory. An even more sophisticated program, called Relikt-2, will continue this work from a halo orbit around the L2 libration point 1.5 million km from Earth (Section 5.4.6). A secondary objective for this mission will be the examination of the geotail plasma (References 67-71).

An even more complex mission to understand better "solar activity, the mechanisms for the transmission of solar effects through the interplanetary medium, and the reactions of near-planet space to solar disturbances" is the subject of the proposed multi-spacecraft

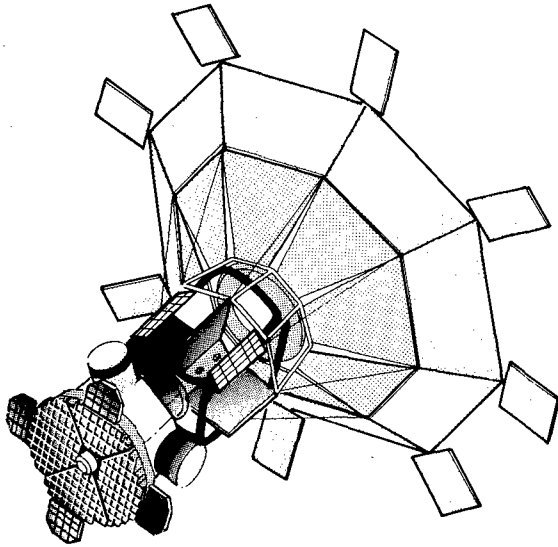


FIGURE 5.9 REGATTA-PLASMA SATELLITE.

Regatta-Plasma mission. The Regatta class of spacecraft represents a dramatic move toward reducing the size, complexity, and hence cost of scientific satellites while still returning valuable data. Conceived by the Institute of Space Research, Regatta satellites would be 500-600 kg platforms with 40-50% of the mass devoted to the scientific payload. A unique aspect of the Regatta configuration (Figure 5.9) is the use of coated solar rudders to control the spin of the spacecraft and a large, immovable solar sail which is aligned with the Sun and acts as a general stabilizer. In a stowed configuration the size of Regatta is no more than 2.35 m tall and 2.5 m in diameter, but in orbit the spacecraft may be up to 3.0 m tall and 9.0 m in diameter.

The Regatta-Plasma mission calls for a constellation of five spacecraft in widely dispersed orbits (Figure 5.10). Regatta-Ye would conduct research within the Earth's radiation belts in an orbit of 500 km by 25,000 km with an inclination of 62.5°. Regatta-A would orbit the Earth in a manner similar to ESA's Cluster satellites (Section 5.2.2), i.e., perigee of 4 RE, apogee of 22 RE, and an inclination of 90°. Regatta-D would follow a complicated path with periodic fly-by's of the Moon. The last spacecraft, Regatta-V and Regatta-S, would be inserted into halo orbits around the L1 and L2 libration points, respectively. This multi-dimensional, time-sensitive network would provide a comprehensive look at the response of the near-Earth environment to solar activity. Initially

proposed for operation during 1994-1997, the Regatta-Plasma mission is now likely to be delayed at least several years due, in part, to restructuring of the Russian space program (References 72-75).

### 5.2.8 Sweden

The launch of Sweden's Freja (a goddess from Norse mythology) satellite by PRC as a piggyback payload on 6 October 1992 marked the nation's second geophysics satellite. In 1986, Sweden launched (piggyback with SPOT-1) the Viking geophysics satellite, which operated for over 14 months. The focus of both missions was observation of the aurora. The Freja project is managed by the Swedish National Space Board and controlled from Swedish Space Corporation's (SSC) Esrange ground

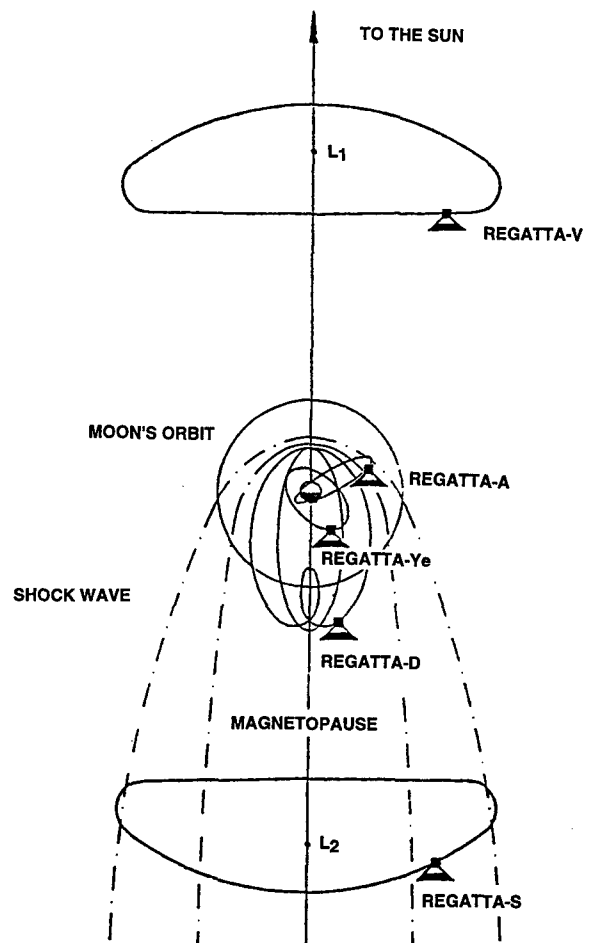


FIGURE 5.10 PROPOSED DISTRIBUTION OF REGATTA-PLASMA SATELLITES.

station. Swedish Space Corporation acted as prime contractor for Freja, while the Max Planck Institute's Institute for Extraterrestrial Physics in Garching, Germany, served as a scientific partner on the project. The eight sensors on Freja (three Swedish, two German, two Canadian, and one American) detect electric and magnetic fields, hot and cold plasmas, waves and particles, and aurora. The 214-kg, 2.2-m diameter, dish-shaped Freja operates in an elliptical orbit of about 600 km by 1,800 km at an inclination of 63° (Reference 76).

From its experience in developing Freja, SSC designed a much smaller satellite platform, Freja-C, with a total mass of less than 30 kg. The first application of the Freja-C bus will be the Astrid 1 spacecraft scheduled for launch in early 1995 by a Russian Cosmos booster as a piggyback payload. From its roughly 1,000-km, 83° orbit, Astrid 1 will image the aurora with two ultra-violet sensors and will also carry an energetic neutral atom analyzer and an electron spectrometer. The 28-kg, spin-stabilized spacecraft is based on a 0.4-m wide cube with four 0.4 m by 0.4 m solar panels. An Astrid 2 spacecraft is tentatively planned for another geophysics mission in a similar orbit in 1996 (References 56, 77-78).

### 5.2.9 United Kingdom

The June, 1994, launches of the STRV 1A and 1B (Space Technology Research Vehicles) spacecraft marked the first time in 10 years

(AMPTE, Section 5.2.3) that the UK had long-lived geophysics satellites in Earth orbit. Although developed by Defense Research Agency as a technology testbed, the STRV program provided an opportunity of acquiring valuable information on the near-Earth radiation and particulate environment. The two spacecraft were inserted in highly elliptical orbits of approximately 280 km by 35,850 km at 7° inclination as piggyback payloads on an Ariane mission. The 50-kg spacecraft (Figure 5.11) with dimensions of 0.4 m by 0.5 m by 0.5 m were equipped with gallium-arsenide solar cells for a beginning of life power level of 30 W. STRV 1A carried cosmic ray sensors (CREDO, Cosmic Ray Effects and Dosimeter), while STRV 1B hosted a UK radiation and proton detector (RADMON, Radiation Monitor) and an ESA radiation environment monitor (REM) for charged particles (References 79-81).

### 5.3 SOLAR SYSTEM INVESTIGATIONS

This section presents solar system exploration programs, both in terms of planetary probes and solar research, i.e., geocentric and heliocentric satellites. Some of the missions described below are coordinated through the International Solar Terrestrial Physics (ISTP) program described in Section 5.2. That section details the missions that are largely Earth-centered, chiefly investigating geomagnetospheric effects, while the programs discussed below focus on the properties and characteristics of other members of the solar system.

#### 5.3.1 European Space Agency

With the successful Giotto comet rendezvous mission (1985-1992) behind (Reference 82), ESA scientists concentrated during 1993-1994 on the culmination of the Ulysses Sun explorer and plans for several more pioneering solar system probes. However, ESA budget realities are likely to retard the growing pace of adopting such challenging missions. The Horizon 2000 long-range space science program created by ESA in 1985 has chosen four cornerstone missions (SOHO/Cluster, XMM, Rosetta, and FIRST) and two medium-size missions (aka M missions: Huygens and INTEGRAL) for both the exploration of the solar system and beyond (the XMM, FIRST, and INTEGRAL missions are covered in Section 5.4.1). Additional M missions and a new Horizon 2000 Plus program are under consideration.

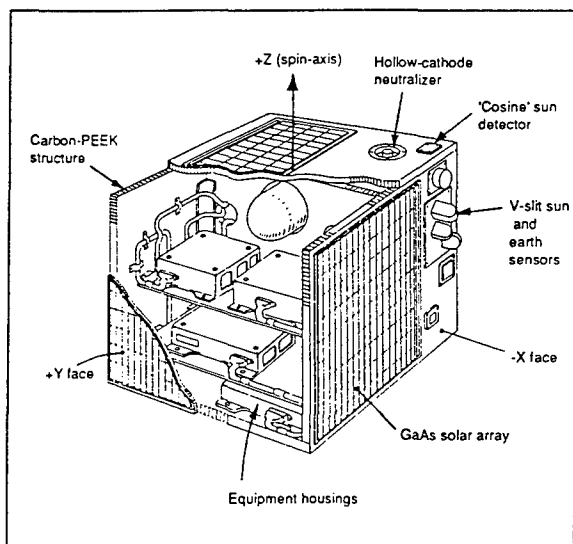


FIGURE 5.11 STRV-1A SATELLITE.



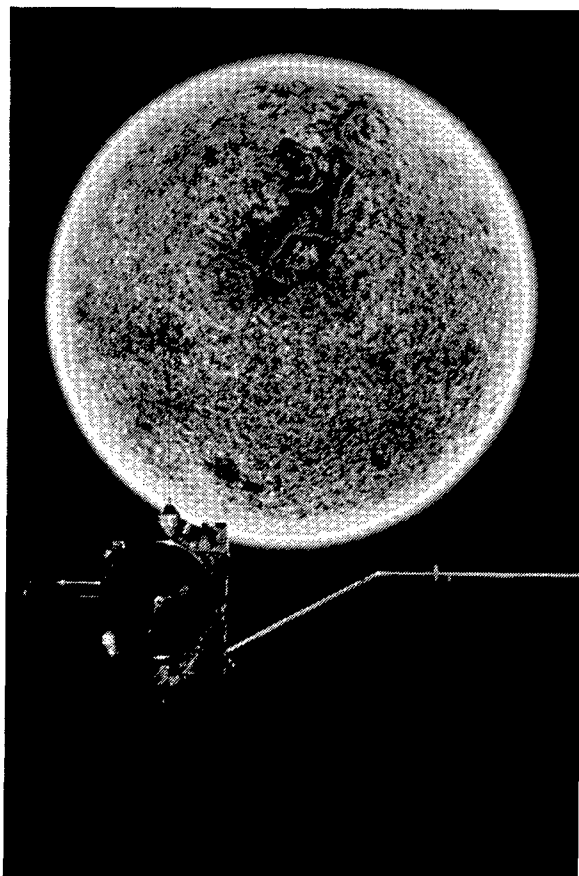


FIGURE 5.12 ULYSSES AT THE SUN.

The Ulysses mission, designed to collect the first close observations of the solar polar regions and 3-dimensional heliosphere data, completed the first of its major objectives in 1994 by reconnoitering the Sun's southern hemisphere. Originally part of a two-spacecraft program between ESA and NASA called the International Solar Polar Mission, Ulysses became a solitary program in 1981 when the US companion spacecraft was canceled. Ulysses then experienced a four-year launch delay in the aftermath of the Space Shuttle Challenger accident, finally being launched in July, 1990, during the STS-41 mission. However, before reaching the Sun the 370-kg spacecraft first had to fly by Jupiter in February, 1992, to receive a gravity-assisted deflection out of the ecliptic and back toward the center of the solar system.

Some 28 months after its encounter with Jupiter, Ulysses began its survey of the Sun's southern latitudes in earnest. From June to October, 1994, the craft monitored the electromagnetic and charged particle environment, reaching a maximum solar latitude of  $-80^\circ$  in

September. Ulysses' trajectory will carry it back across the ecliptic in early 1995 with a closest approach of 200 million km and then over the northern hemisphere for another polar campaign during June-September. After completing this survey of the Sun, Ulysses will follow a trajectory back toward the orbit of Jupiter. Aphelion should occur in 1998 although Jupiter will be more than 100 million miles away. If Ulysses is still functioning, a second, close-up survey of the Sun could commence late in the year 2000 when the spacecraft once again approaches the solar southern regions.

The spin-stabilized (5 rpm) spacecraft (Figure 5.12) is powered by a US-supplied radioisotope thermoelectric generator. A complex array of more than a dozen scientific instruments comprise the 55-kg payload. The prime contractor was Dornier with British Aerospace (now Matra Marconi), DASA, and Fokker as major subcontractors (References 83-91).

The Sun will be monitored from afar with the 1995 launch of ESA's Solar Heliospheric Observatory (SOHO). Placed in a halo orbit about the L1 libration point (between the Earth and the

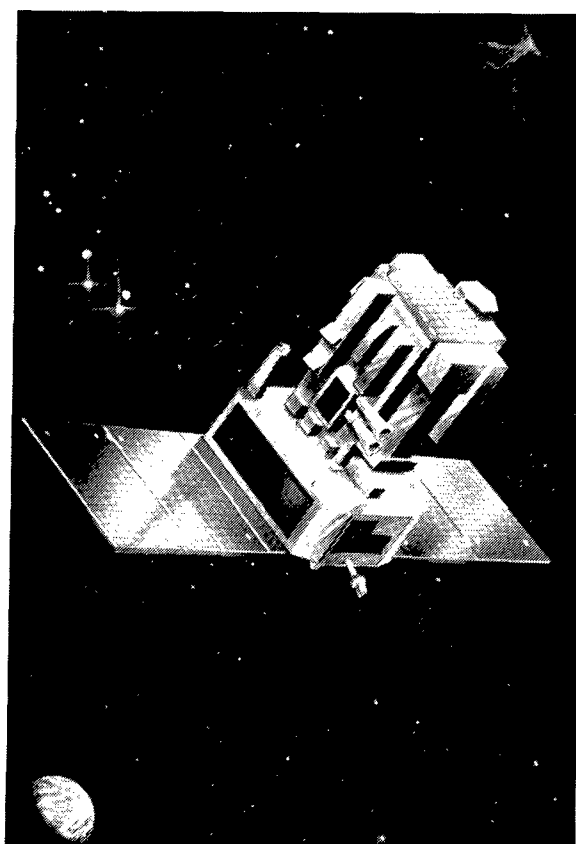


FIGURE 5.13 SOHO SATELLITE.



Sun), SOHO (Figure 5.13) will conduct a 3-part program of helioseismology, solar atmosphere remote sensing, and in situ solar wind observations as ESA's second half of the STSP (Section 5.2.2). In cooperation with NASA, SOHO will be launched by an Atlas-Centaur booster.

A contractor team led by Matra Marconi was hard at work during 1993-1994 testing and integrating the spacecraft (Figure 5.14). With an initial mass of 1,850 kg, SOHO is 3.65 m in diameter and 3.8 m tall with a solar array span of 9.5 m. The 3-axis stabilized spacecraft will carry a 610-kg payload of 12 major instruments: three for helioseismology (GOLF, VIRGO, and MDI/SOI), six for solar atmosphere observations (SUMER, CDS, EIT, UVCS, LASCO, and SWAN), and three for solar wind measurements (CELIAS, COSTEP, and ERNE). The design lifetime is two years with reserves available for up to four additional years (References 92-96).

ESA's next solar system exploration program will be directed toward the outer reaches of the solar system: Saturn's moon Titan. The US-ESA Cassini/Huygens mission (Figure 5.15) will place the first artificial satellite in orbit around Saturn and the first man-made probe in the atmosphere of Titan. ESA's 375-kg 2.7-m

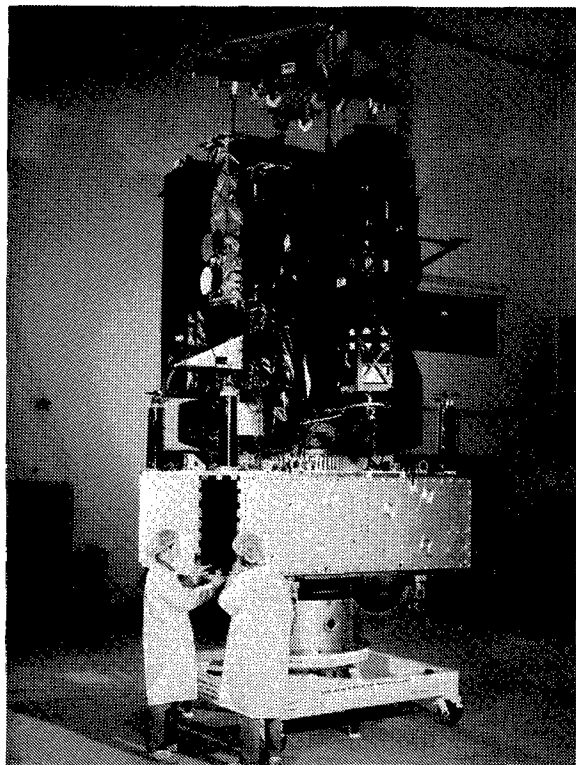


FIGURE 5.14 INTEGRATION OF SOHO STRUCTURAL MODEL.

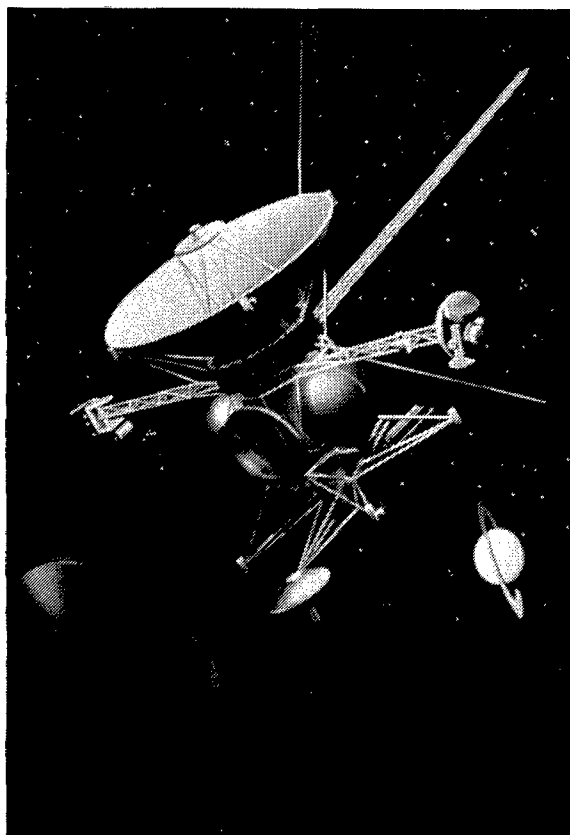
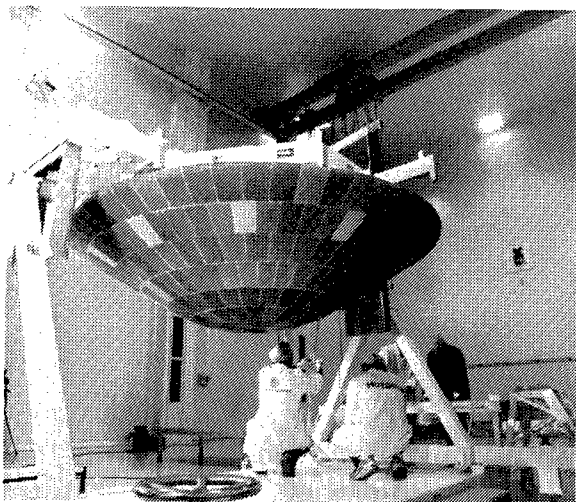


FIGURE 5.15 CASSINI AND HUYGENS PROBE IN THE SATURN SYSTEM.

diameter Huygens atmospheric vehicle (aka the M1 mission) is scheduled to encounter the distant moon in late November, 2004, after a launch with Cassini by a Titan 4 booster in October, 1997, and gravity assists by Venus (2), Earth, and Jupiter. During 1994 Huygens' heat shield of 160 tiles of silica fibers, designed to withstand entry temperatures up to 2,000°C, was being carefully fabricated (Figure 5.16).

A complement of six major instruments will be in operation during the 3-hour atmospheric descent: Aerosol Collector and Pyrolyzer (ACP), Descent Imager/Spectral Radiometer (DISR), Doppler Wind Experiment (DWE), Gas Chromatograph Neutral Mass Spectrometer (GCMS), Huygens Atmospheric Structure Instrument (HASI), and Surface Science Package (SSP). If the probe survives the impact on Titan, battery life will probably severely limit the amount of subsequent information which may be returned. The prime contractor for Huygens is Aerospatiale (References 97-103).

After many years of planning and conceptual design, initially in conjunction with NASA, the Rosetta Primordial Bodies mission was selected by ESA in November, 1993, as the



**FIGURE 5.16 HUYGENS PROBE HEAT SHIELD IN FABRICATION AND TESTING.**

third cornerstone of the Horizon 2000 space science program. The revised 1994 mission profile called for a launch in January, 2003 for a rendezvous with Comet Wirtanen in late 2011, remaining with the natural body through perihelion passage in 2013. The objective of the mission is to "undertake remote sensing of the nucleus and the near-coma and carry out in situ measurements of the surface using a small deployed instrument package" (Reference 104). (The original ESA-NASA plan envisioned a more challenging comet nucleus sample return.) Later, the surface instruments were separated into two surface science packages (SSPs). The candidate spacecraft bus is a variant of Matra Marconi's Eurostar GEO communications satellite (Figure 5.17). The spacecraft and payload are still in the definition and early design phase (References 104-111).

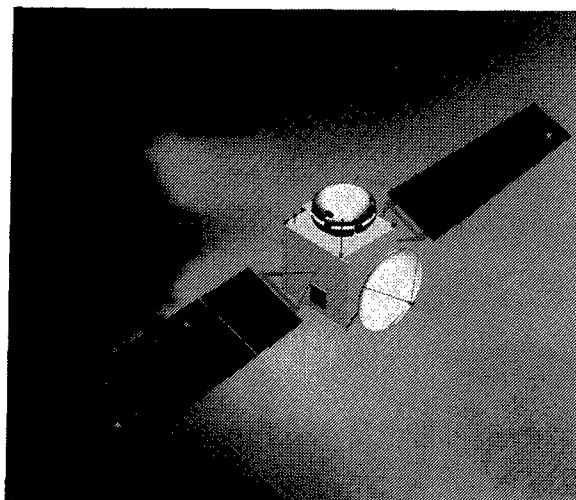
Candidate selection for the M3 mission narrowed considerably during 1993-1994, leaving only five proposals for Phase A development by the end of the period. Two of the five have solar system exploration objectives: InterMarsNet and MORO (Moon Orbiting Observatory). The InterMarsNet project calls for the deployment of several landers on Mars to monitor the environment and report back to Earth via an orbiter spacecraft. The project could become a broader international endeavor with participation by the US, the Russian Federation or other countries. MORO would be a 1,200-kg class spacecraft, possibly with a small subsatellite, given a primary mission of high resolution stereo imaging of the lunar surface. Another M3 proposal for a

Mercury orbiter was dropped in 1994 but may be reconsidered under a different mission opportunity. The tentative launch date for M3, which should be chosen by 1996, is 2003 (References 112-116).

The Horizon 2000 Plus space science program remains in the formative stage, but two proposals, including a Mercury orbiter, already have strong internal support. Launches are anticipated in the 2006-2016 time-frame (References 117-119). Meanwhile, a separate effort is underway by some ESA members to adopt a more aggressive lunar exploration program which would include lunar landers and automated lunar scientific stations (References 120-122).

### **5.3.2 France**

Aside from its considerable involvement with the ESA programs, France also launched a modest Jupiter research mission on 17 July 1991. The SARA (Satellite for Amateur Radio Astronomy) spacecraft, designed by college students at the Ecole Supérieure d'Ingénieur en Electrotechnique et Electronique in Noisy le Grand, was fielded with support from CNES and French aerospace companies. The mission of the microsatellite was to monitor the Jovian atmosphere for radio emissions in pursuit of a better understanding of the giant planet's magnetosphere. The 19-kg, 0.4 m per edge, cubic SARA, which was deployed from an Ariane 4 ASAP (Ariane Structure for Auxiliary Payloads) platform, was inserted into a 770 km by 777 km, 98.54° inclination orbit. Unfortunately, a malfunction prevented the return of any useful data,



**FIGURE 5.17 ROSETTA SATELLITE.**

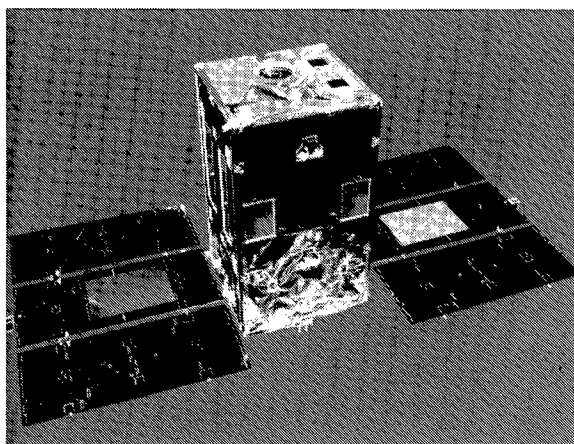


FIGURE 5.18 SOLAR-A (YOHKOH) SATELLITE.

and no further missions of this nature are firm (Reference 123).

### 5.3.3 India

In 1982 the Indian Space Research Organization announced ambitious plans to conduct planetary exploration missions, specifically identifying Mars, Mercury, and Venus as high priority candidates. The missions, which could commence around the turn of the century, would be launched by India's GSLV, now scheduled for its maiden flight in 1998. A proposed 250-kg class Mercury orbiter has already attracted some attention with a suite of scientific instruments which could include high-resolution cameras, magnetometers, and multi-band radiometers and spectrometers. No program commitments had been made by the end of 1994 (References 124-126).

### 5.3.4 Japan

Japan has a growing portfolio of solar system investigations, and planned future missions will further expand Japan's position via direct solar system exploration. To date ISAS, rather than NASDA, has been the primary agency involved with such missions. Starting in 1971 with the Shinei (New Star) satellite, ISAS has fielded four solar research experiments, culminating with the Yohkoh (Sunbeam) probe, also known as Solar-A (Figure 5.18), on 30 August 1991 from the Kagoshima Space Center. The 420-kg, 2 m by 1 m by 1 m box-shaped satellite resides in low-Earth orbit (515 km by 745 km, as of 31 December 1994) with four solar sensors: hard and soft X-ray telescopes, a Bragg

crystal spectrometer and a wide-band spectrometer. Yohkoh is the first satellite to provide continuous 'video' of events in the X-ray and gamma-ray spectra and has already inundated solar researchers with hundreds of thousands of high-quality images. The particular bands chosen yield data on the activity of high-temperature gases and high-energy phenomena on the Sun's surface. The project also involved researchers in the US and UK (References 58, 127-130).

Japan launched its first deep space probes in 1985 as part of the international fleet to study Halley's comet. The Sakigake (Pioneer) and Suisei (Comet) probes were more distant observers than ESA's Giotto but returned much valuable information on the Halley-induced space environment. Both spacecraft were short, spin-stabilized drums with a total mass of about 140 kg. Although Suisei failed in 1991, Sakigake (Figure 5.19) was still operational at the end of 1994. In recent years it has returned valuable information on the solar system medium and the Earth's magnetosphere (References 131-132).

Japan's first lunar mission, Muses-A (aka Hiten, Figure 5.20), came to an abrupt end on 11 April 1993 when the 1.4-m diameter, 0.85m tall, 180-kg spacecraft completed its 3-year mission with an impact near the crater Furnerius. From January, 1990, to February, 1992, Muses-A had traveled around the Earth-Moon system in a variety of winding trajectories before finally

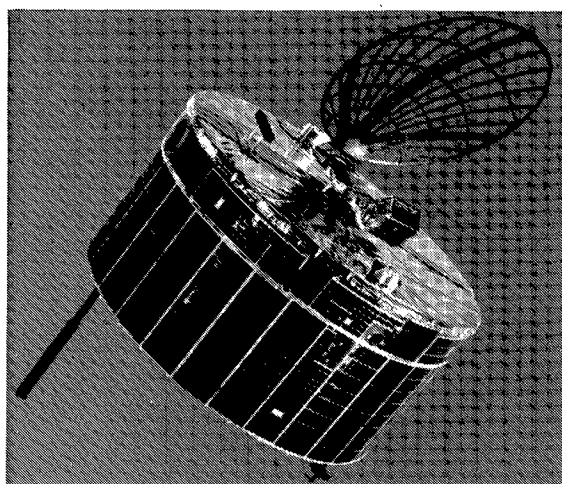


FIGURE 5.19 MS-T5 (SAKIGAKE) SATELLITE.

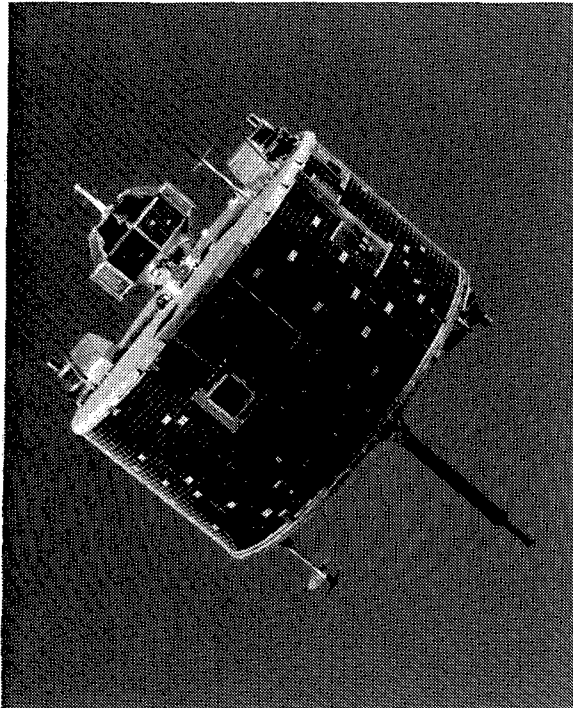


FIGURE 5.20 MUSES-A (HITEN) WITH HAGOROMO LUNAR ORBITER ATTACHED (TOP).

entering lunar orbit. Early in the mission, a small 11-kg sub-satellite called Hagoromo had been injected into lunar orbit but a communications failure resulted in the return of no useful data (References 133-137).

ISAS has two major solar system exploration projects under development for 1997-1998 launches: Lunar-A and Planet-B. Both spacecraft will take advantage of the new, greater capacity M-5 launch vehicle to be introduced in 1996 or 1997. The Lunar-A mission profile (Figure 5.21) envisions both a mapping lunar orbiter and small penetrators for seismic and thermal studies of the Moon. The orbiter will deploy three probes to the Moon over a one month period in 1998 after launch in 1997. The 0.12 m diameter by 0.80 m instrumented spikes will impact the lunar surface (two on the nearside and one on the farside) at about 300 m/s and will return heat loss information and seismic data on moonquakes in an attempt to determine the core state of the Moon, which has puzzled researchers for decades. The 2.2 m diameter by 2 m high, 500-kg orbiter will then assume a low altitude lunar mapping and data relay orbit, probably with a CCD camera. Imagery detail may be about 20 m. The data from both studies should aid in mission definition and planning for

future manned lunar visits and/or bases. Lunar-A will draw on the experience in lunar transfer orbits and subsatellite deployment gained with the Hiten/Hagomoro mission (References 138-142).

The second pending interplanetary ISAS mission is Planet-B (Figure 5.22), a Mars orbital mission due for launch in 1998 with arrival at the Red Planet in 1999. The primary goal of the 35-kg payload will be to study the interaction of the solar wind with Mars' atmosphere. Mars has a very weak magnetic field as compared with Earth and all other planets except Venus, thus it is suspected that the unobstructed solar wind strips away much of the Martian atmosphere. The spacecraft will weigh approximately 540 kg at launch with a bus diameter of 2.0 m. The spin-stabilized (7.5 rpm) Planet-B will also feature two solar arrays capable of producing up to 200 W in Mars orbit, a 5-m long mast, a 1.7-m long boom, and four wire antennas about 25 m in length. Twelve principal instruments have been selected to measure the local particles and fields in addition to mapping the Martian

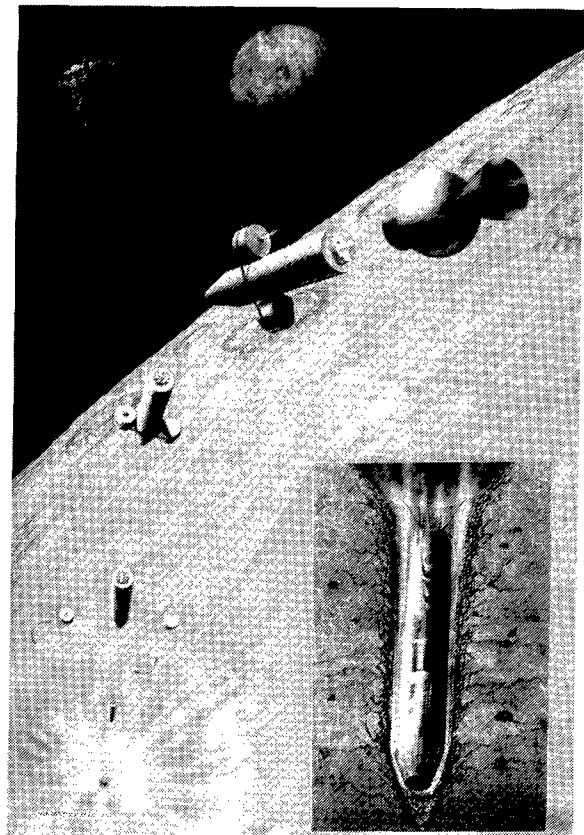


FIGURE 5.21 LUNAR-A ORBITER AND PENETRATORS.

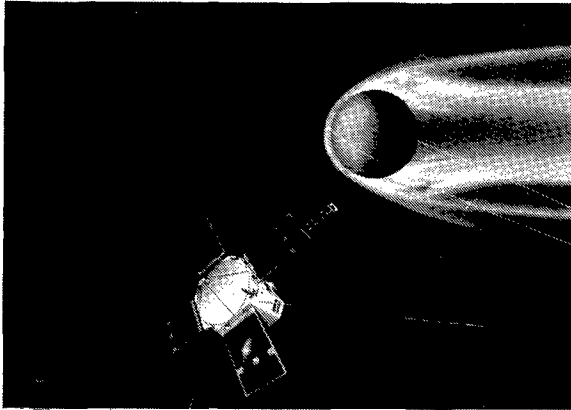


FIGURE 5.22 PLANET-B MARS ORBITER.

surface from altitudes ranging from 150 km to 30,000 km (References 143-148).

ISAS is also considering a wide variety of proposals for missions to be launched early in the next century. Currently under study are the Nereus asteroid sample return project, the SOCCER comet sample return mission, and Venus exploration programs employing planetary orbiters and atmospheric balloon probes.

Japan's larger space agency, NASDA, is developing plans to conduct its very first deep space missions, some in conjunction with ISAS. With the help of NASDA's much larger H-II launch vehicle, more sophisticated missions can be attempted. A series of lunar missions, beginning with a lunar orbiter and progressing to lunar rovers and sample return missions, has been recommended. Particular interest has been generated in the possibility of extracting Helium-3 from the lunar surface. Even more grandiose, manned lunar bases are under study by both government and industry. A Mercury sample return mission and an automated Martian rover are also being considered (References 149-156).

### 5.3.5 People's Republic of China

Budgetary and technical constraints have heretofore hindered Chinese aspirations of solar system exploration. In 1992 a senior Chinese official indicated his country's desire to participate in planetary missions, particularly to Mars. The PRC has played a very minor role in the Russian-led Mars-98 mission. The first national deep space science mission may be a lunar orbiter, currently under study for a possi-

ble launch at the turn of the century (References 157-158).

### 5.3.6 Russian Federation

For three decades (1959-1988) the former Soviet Union was at the vanguard of solar system exploration, repeatedly achieving historic milestones such as the first lunar flyby, lunar impact, lunar lander, lunar orbiter, unmanned lunar sample return, lunar rover, Venus atmospheric and surface probes, and Venus radar mapper. At the 30th anniversary celebrations of the launch of Sputnik 1, Soviet officials painted an ambitious plan for solar system exploration of nearly a dozen complex missions targeting natural bodies from the Sun to as far away as Saturn. However, only the Phobos missions of 1988, which were less than a year from launch, ever left the Earth, and both of those spacecraft failed in their primary missions. The Russian Federation, the beneficiary of a great solar system exploration legacy, is now struggling to launch two Mars-bound spacecraft before the end of the decade. All other proposed flights will undoubtedly be deferred until the next century (Reference 159).

The year 1994 was supposed to witness the launch of the now-international Mars-94 spacecraft, designed to place a heavy platform into Mars orbit and to drop four small probes onto the Martian surface. Originally conceived as the Columbus Project with a 1992 launch date, Mars-94 was redefined and simplified several times before its rescheduled launch in October, 1994, with only a single spacecraft. The Russian-led mission now included substantial participation from the former Soviet bloc nations, France, Germany, UK, Japan, US, and others - more than 20 countries in all.

The Mars-94 hardware and mission profile are depicted in Figure 5.23. The cruise spacecraft is shown with the surface experiments on-board during the journey to the Red Planet after launch by a Proton booster. A few days before reaching Mars, the two small station surface probes are released for a direct entry into the Martian atmosphere. The two penetrator probes are released from the mother spacecraft after a stable Mars orbit has been obtained. All four landers will be powered by radioisotope thermoelectric generators (RTGs) to permit lifetimes of up to one year. The orbiter will revolve about Mars in highly elliptical, 12-15 hour orbits to carry-out its own intensive survey of the planet

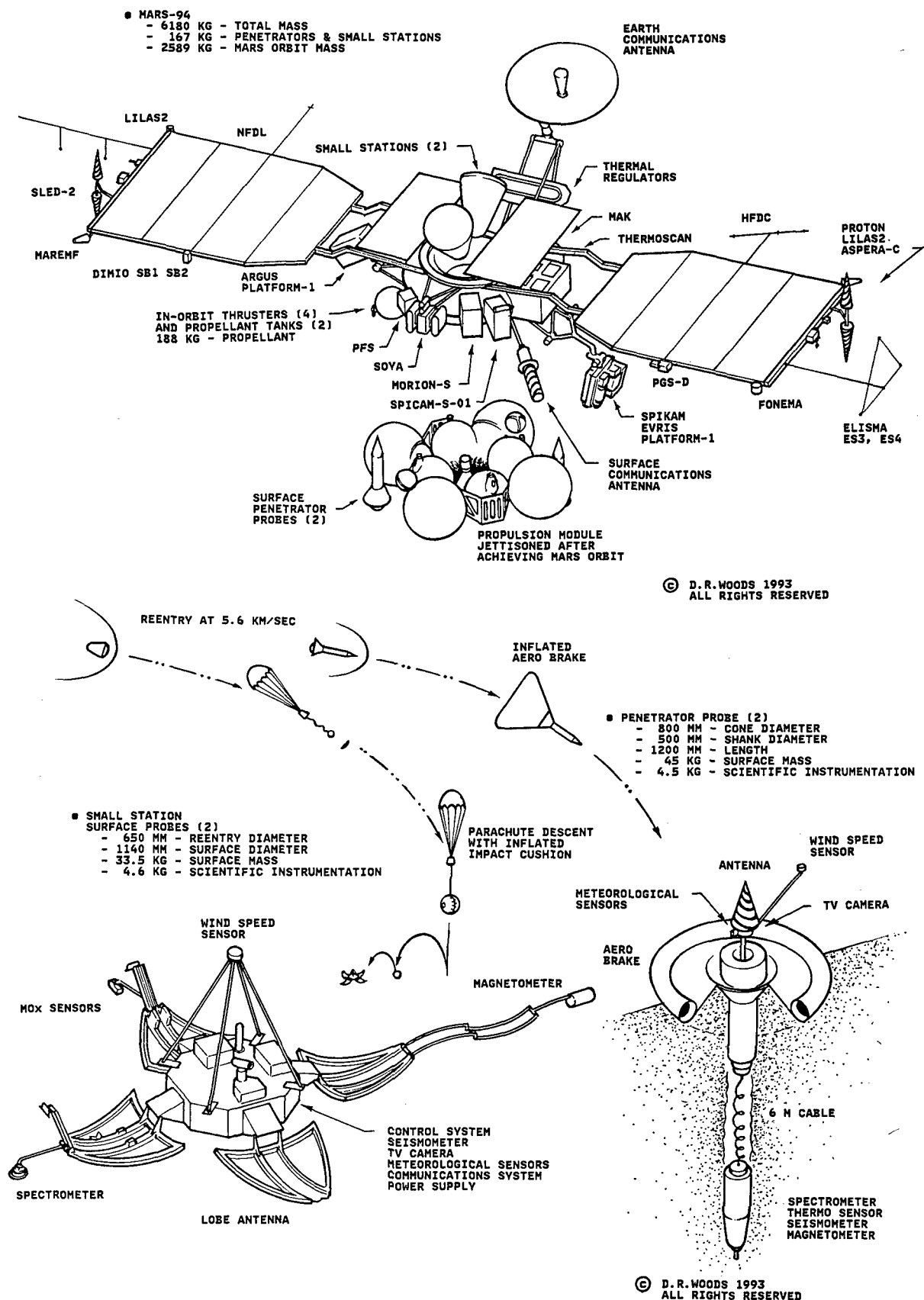


FIGURE 5.23 MARS-96 (FORMERLY MARS-94) ORBITER AND LANDING PROBES.



and to serve as a data collector from the surface instruments. The scientific program is managed by the Russian Academy of Sciences' Institute of Space Research, while the Babakin Engineering and Research Center of the Lavochkin Scientific Production Association is responsible for most spacecraft hardware, excluding the scientific instruments (References 160-162).

From high hopes and strong commitments in early 1993, the Mars-94 program began to gradually unwind as the year progressed with severe doubts by the end of the year that the launch schedule could be achieved (References 163-171). By April 1994, just six months before the planned lift-off of Mars-94, the Russian Space Agency decided the mission would have to be postponed until the next flight opportunity in 1996. Unfortunately, the launch window for the newly rechristened Mars-96 will not be as favorable as the 1994 window, leading to a reduction in payload or equally undesirable changes in the flight profile. By the end of 1994 worries about a complete cancellation of the

project had surfaced (References 172-179). Figures 5.24 and 5.25 illustrate the latest configuration of the Mars-96 orbiter and small station, respectively.

The two-year delay for the former Mars-94 had the expected domino effect of revising the original Mars-96 mission launch to 1998, thereby changing its name to Mars-98. The main Mars-98 scientific payloads are an atmospheric balloon probe and a miniature Mars rover, both originally envisioned for the 1992 Columbus Project, temporarily moved to Mars-94, and then manifested on Mars-96 (now Mars-98). The balloon probe is primarily a Russian-US-French undertaking with a total mass of 65 kg and a design life of 10 days during which it may travel up to 1,500 km across the planet, dragging an instrumented package along the surface each night. The rover is a product of the Russian Institute of Transport Mechanical Engineering with a mass of 75-80 kg, a width of 0.95 m and a length of 0.7-1.2 m, depending upon the terrain (Figure 5.26). Like the Mars-96 landers, the rover will be powered by a small

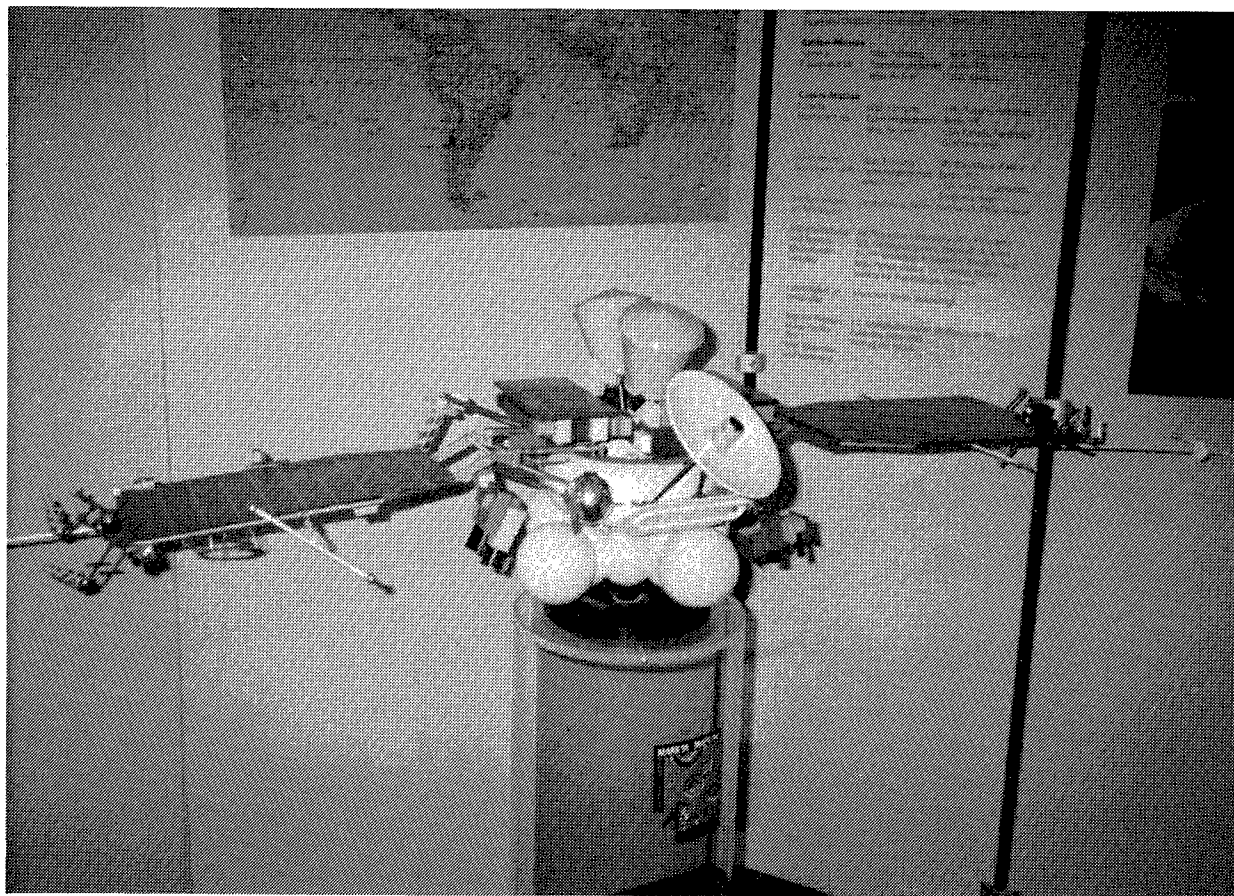


FIGURE 5.24 MARS-96 MODEL WITH LANDING PROBES.

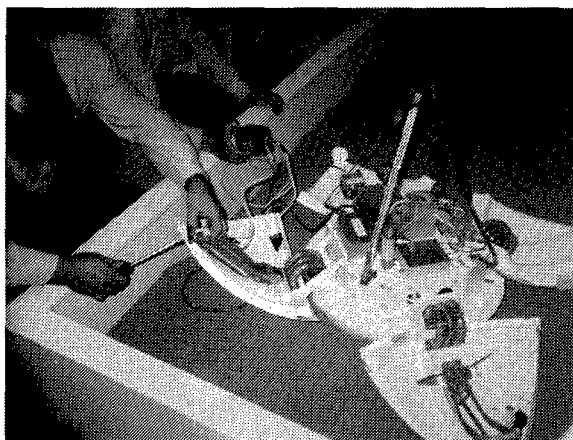


FIGURE 5.25 MARS-96 LANDING STATION.

RTG. The Mars-98 main spacecraft will relay data from the balloon and rover to Earth from its orbit about Mars. Engineering models of the balloon and the rover have been undergoing extensive tests on Earth for several years. However, by late 1994 new concerns about the viability of Mars-98 were raised, including the possibility that the payload would be dramatically downsized to accommodate a launch by a Molniya rather than a Proton booster (References 180-195).

With the disarray existing within the Russian solar system exploration program, no commitments to other missions have been made. However, a number of proposals retain a very high level of interest within the scientific community, and behind-the-scenes negotiations are underway to find either domestic or international financial support. Perhaps the most likely next mission will be a joint US-Russian project to send an instrumented vehicle past Pluto and dropping a probe on its surface, the oft-discussed Pluto Fast Fly-by mission. One scenario envisions a spacecraft launched in 1999 by a Russian booster reaching Pluto in the period 2006-2007. Another joint US-Russian mission, based on the new American Discovery program, would renew Venus studies under the Surface-Atmosphere Geochemistry Experiments (SAGE) concept, taking advantage of Russian Venus lander technology. Finally, a number of lunar exploration missions have been suggested with an emphasis on lunar rovers and exploitation of lunar materials (References 196-211).

On a more positive note, after several years of delays the Russian Federation in conjunction with the Ukrainian Space Agency launched the first of two planned KORONAS (Complex

Orbital Near-Earth Observations of Activity of the Sun) Earth-orbiting solar observatories. KORONAS-I was launched on 2 March 1994 by a Tsyklon-3 booster from the Plesetsk Cosmodrome and inserted into an orbit of 487 km by 528 km at an inclination of 82.5°. The foci of the KORONAS-I investigations are solar neutrino emissions (via helioseismology) and the structure of the high temperature regions of the solar atmosphere. The principal scientific instruments included the TEREK-C multi-channel imaging telescope and coronagraph, the GELIKON and DIOGENESS solar flare analyzers, the IRIS solar flare spectrometer, the AVS solar gamma-ray detector, the SUFR-SP-K radiometer and the VUSS spectrometer for ultraviolet investigations, the DIFOS solar optical photometer, and the SKL cosmic ray spectrometer.

The KORONAS-I spacecraft is the first use of the new Ukrainian AUOS-SM-AI platform (Figure 5.27), designed and manufactured by the Yuzhnoye Scientific Production Association. The original AUOS (Automatic Universal Orbital Station) platform has been in use since 1976. The 2,300 kg spacecraft includes 410 kg for the scientific instruments. KORONAS-I has a diameter of 2.3 m and a height of 5.0 m with a total span of 12.8 m with all solar panels and antennas deployed. The 3-axis stabilized spacecraft is the first AUOS spacecraft to be solar-oriented. The launch of the sister KORONAS-F

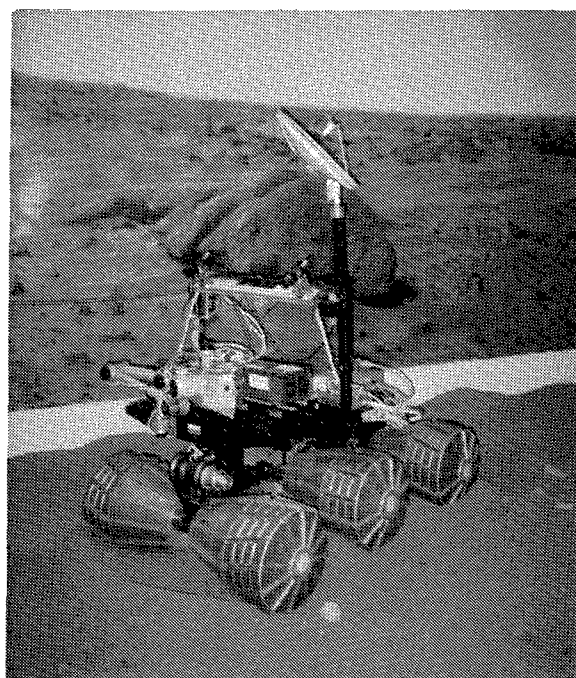


FIGURE 5.26 MARS-98 MARS ROVER.



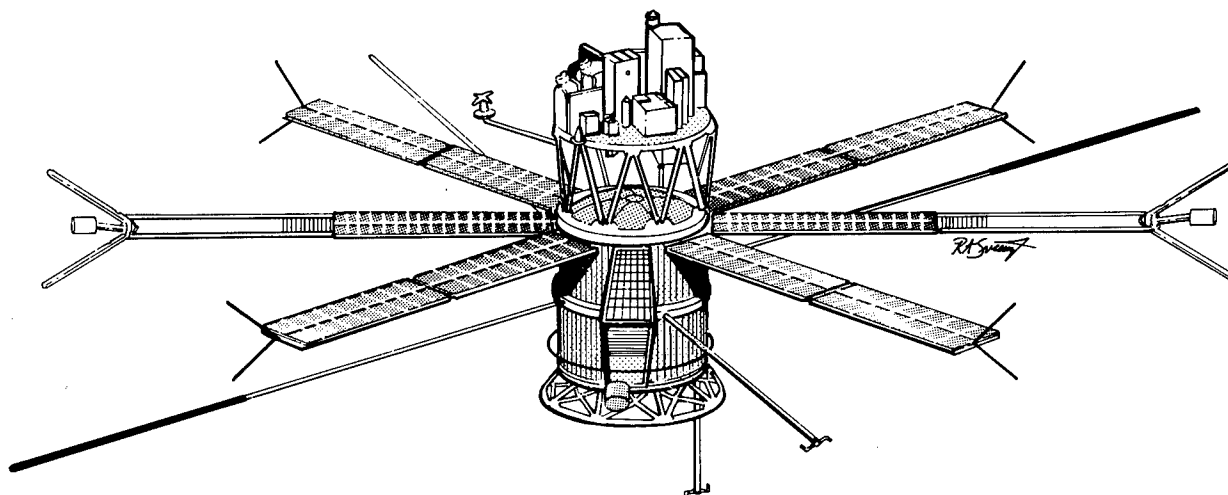


FIGURE 5.27 AUOS-SM PLATFORM FOR KORONAS MISSIONS.

spacecraft has been delayed indefinitely. In addition to Russian and Ukrainian support, the KORONAS program has enjoyed the participation of Poland, Bulgaria, the Czech Republic, Slovakia, Germany, France, and the US. The mission design life is 6-7 years (References 212-219).

Another proposed application of the small Regatta spacecraft (Section 5.2.7) is the SAPS (Solar Activity Patrol System) project, previously known as SPAS (Solar Patrol and Alert Satellite). The purpose of the system, with one or more Regatta spacecraft in a halo orbit about the L1 libration point between the Earth and the Sun (1.5 million km from Earth), is to provide warning of approaching solar phenomenon. Specifically, realtime notification of solar flares and proton events, half-hour warning of approaching solar wind shock wave, and short-term forecasts of solar activity are the program objectives. To date, no formal program approval has been made (References 220-221).

#### 5.4 EXTRA-SOLAR SYSTEM OBSERVATIONS

The use of man-made satellites to perform surveys of the Universe beyond our small Solar System has revolutionized the field of astrophysics in the second half of the 20th century. Not only have orbital platforms made possible the collection of electromagnetic spectra normally screened by the Earth's atmosphere, but these satellites can operate beyond the influence of other geophysical perturbations and can permit the establishment of very long baselines (greater than the diameter of the Earth)

necessary for some radio astronomy investigations.

Due to their complex, often state-of-the-art nature and to their often one-of-a-kind status, modern deep space astrophysical observatories may require strong governmental support. In Europe and Asia, the Russian Federation, ESA, and Japan have been the leaders in this field while India strives to increase its contribution. However, the growing international cooperation in space science missions has in large measure eroded previous national distinctions. Despite severe economic pressures facing virtually all national space programs, a large number of significant extra-Solar System observation missions are planned for the remainder of this decade.

##### 5.4.1 European Space Agency

Since the establishment of ESA, space science, including extra-solar system observations, has been considered one of the foundations of the multi-national organization. (ESA's predecessor, ESRO, fielded numerous scientific satellites, including its first spacecraft in 1968 with cosmic ray detectors.) From its initial cooperation with the US and UK on the International Ultraviolet Explorer (launched 1978 and continuing to operate through 1994), ESA undertook a program of autonomous missions, beginning with the European X-ray Observatory Satellite (EXOSAT), while continuing its participation with other countries, e.g., the Hubble Space Telescope. The period 1993-1994 was marked by considerable activity in preparing for a flurry of deep space observatories scheduled

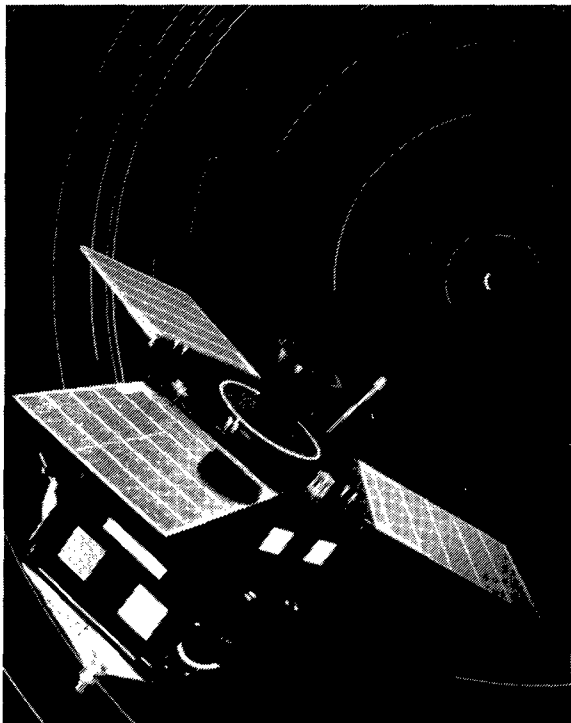


FIGURE 5.28 HIPPARCOS SATELLITE.

for launch during 1995-1996. A new medium class mission was also approved as the first ESA science mission of the 21st century.

ESA was a significant participant in the Hubble Space Telescope (HST) project, providing the solar arrays (British Aerospace) and the Faint Object Camera (Dornier). While the latter has performed well, albeit originally at reduced fidelity due to the primary mirror problem, soon after launch in April, 1990, the solar arrays were found to be susceptible to thermal effects when crossing the terminator, in turn upsetting the stability of the telescope. During the first Hubble servicing mission (STS-61) in December, 1993, the solar arrays were replaced, and a corrective optics package was installed. ESA's Claude Nicollier was responsible for capturing and releasing the unique orbital telescope with the shuttle arm (Reference 222).

In 1989 ESA launched the High Precision Parallax Collecting Satellite (HIPPARCOS) for the purpose of compiling an accurate catalog of stellar positions. Although a launch malfunction

left the 1.14 metric ton satellite stranded in GTO instead of the intended GEO, ESA engineers and space scientists were able to salvage much of the program's objectives despite the less than optimum conditions. By 1992, precise astrometric measurements of 120,000 stars had been made with the desired accuracy of two milli-arcseconds under the Main Experiment, and a mission extension had been granted. A secondary objective, code-named the Tycho Experiment, called for obtaining positional data (30 milli-arcsecond accuracy) and two-color photometric properties of 400,000 additional stars. The mission was terminated on 15 August 1993 (References 223-227).

The HIPPARCOS satellite's basic structure was a hexagonal box with three rectangular solar panels extending from the base (Figure 5.28). The spacecraft maintained a very slow spin rate ( $\sim$  one revolution every two hours) to facilitate its all-sky mapping mission. At the end of its mission the orbital parameters of HIPPARCOS were about 490 km by 35,880 km at an inclination of  $6.8^\circ$ . Matra Marconi was the prime contractor for the satellite with significant contri-



FIGURE 5.29 ISO SATELLITE.

butions from the major European aerospace industries, including Dornier, Fokker, ERNO, and British Aerospace.

The next major astrophysical mission of ESA is the Infrared Space Observatory (ISO), scheduled for launch in late 1995. Selected in 1983, ISO will expand upon the work of the pioneering US-UK-Netherlands Infrared Astronomical Satellite (IRAS), launched in 1983. However, "compared with IRAS, ISO will have a longer operational lifetime, wider wavelength coverage, better angular resolution, more sophisticated instruments, and, through a combination of detector improvements and longer integration times, a sensitivity gain of several orders of magnitude" (Reference 228). Whereas IRAS was designed to map the IR celestial sphere, ISO will make more detailed observations of selected objects.

ISO will have an initial mass of 2.5 metric tons in a compact structure 5.3 m in length and 2.3 m in width (Figure 5.29). The precision attitude control system will provide a pointing accuracy of 2.7 arcseconds. Electrical power will be furnished by solar cells mounted on the exterior of the Sun shield. ISO's operational orbit will be 1,000 km for perigee and 70,000 km for apogee at a low inclination, and the spacecraft will be controlled from ESA's Villafranca ground station in Spain (References 228-235).

The heart of ISO is a cryogenically-cooled Ritchey-Chretien telescope with an effective aperture of 60 cm. Approximately 2,300 liters of superfluid helium will be carried to cool the infrared detectors and scientific equipment to 2-3° K for a period of at least 18 months. The principal instruments are (1) ISOCAM camera and polarimeter operating at 2.5-17  $\mu\text{m}$ , (2) ISO-PHOT imaging photopolarimeter operating at 2.5-200  $\mu\text{m}$ , (3) SWS short-wavelength spectrometer operating at 2.4-45  $\mu\text{m}$ , (4) LWS long-wavelength spectrometer operating at 45-180  $\mu\text{m}$ .

ISO's prime contractor is Aerospatiale with a team of about 35 subcontractors, including Fokker, DASA, and Dornier. Difficulties with the cryogenic cooling system have been the principal reason for the more than two year delay encountered thus far in the project. In addition, the flight model telescope was rejected due to excessive contamination and blemishes on the primary mirror. The mirror was replaced, and the telescope rebuilt.

In 1985 ESA set forth its Horizon 2000 program for space science investigations with four "cornerstone" missions. The first cornerstone is STSP (Section 5.3.6), scheduled to begin solar studies with SOHO and Cluster in 1995. The second cornerstone mission, now slated for launch in 1999, is the High-Throughput X-ray Spectroscopy Mission known as the X-ray Multi-Mirror (XMM) observatory. The objective of the program is to collect "high-quality spectral measurements of faint sources down to  $2 \times 10^{-15}$  erg/cm<sup>2</sup>/s together with fast low- and medium-resolution spectroscopy of brighter objects" (Reference 236) as a follow-on to ESA's earlier EXOSAT mission.

The XMM spacecraft will be approximately four metric tons at launch and will be inserted into an elliptical 48-hr orbit with an inclination of 65°. The design of XMM solidified during 1993-1994, but a recompetee for a prime contractor was conducted in 1994 after allegations of anti-competitive collusion. The new winner is DASA with Karl Zeiss (Germany) and Medialario (Italy) providing the critical mirror and mirror shell components. Current project emphasis is on perfecting the manufacturing process of the required three mirror modules sensitive to 1-50 Å waves and made up of 58 nested mirror shells. Three primary instruments have been identified: (1) European Photon Imaging Camera for each mirror module to provide broadband spectrophotometry with CCD arrays, (2) Reflection Grating Spectrometer for two mirror modules to provide medium resolution spectroscopy using reflection gratings, and (3) Optical Monitor consisting of a 30 cm diameter Cassegrain telescope for simultaneous optical coverage of the X-ray telescope field (References 237-243).

The fourth Horizon 2000 cornerstone mission (confirmed in November, 1993) still in the early design phase is the Far-Infrared and Submillimeter Space Telescope (FIRST) with a tentative launch date of 2006. The objective of the mission is to acquire high precision imaging in the 50  $\mu\text{m}$ -1 mm portion of the electromagnetic spectrum to study the physics of the interstellar medium, star formation, and cosmology. The original design called for a primary telescope of 4-8 m diameter, but in 1992 budget pressures led to a downsizing of the diameter to only 3 m. In turn this leads to an emphasis on the 200-600  $\mu\text{m}$  region with heterodyne spectroscopy - a

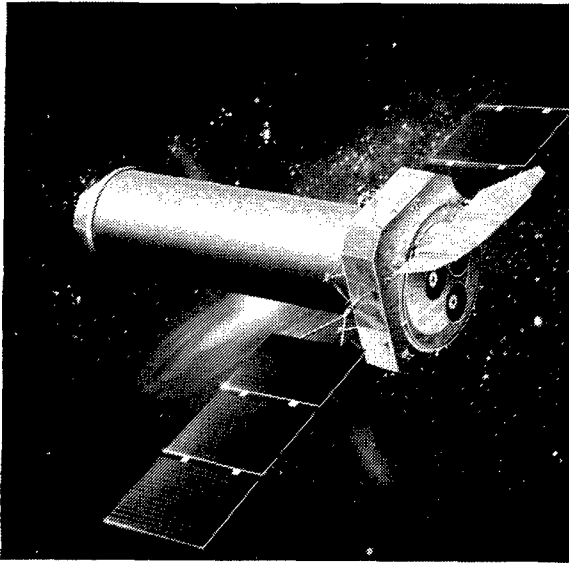


FIGURE 5.30 XMM SATELLITE DESIGN.

technique which eliminates the need for liquid helium cryogenic cooling. Spectrometers and photometers tuned to 50-900  $\mu\text{m}$  are also anticipated. The roughly two-metric-ton spacecraft will operate in a 24-hour, elliptical Earth orbit (References 244-246).

The second Medium Mission (M2) was selected in 1993 for a launch in 2001. The International Gamma-Ray Laboratory (INTEGRAL) will concentrate on high resolution spectroscopy and precision mapping of gamma-ray sources in the 15 keV to 10 MeV regime. The Russian Federation and the US will also participate in the project, and in a departure from normal operations a Horizon 2000 spacecraft may be launched by a foreign booster, i.e., the Russian Proton. The use of the Proton will permit INTEGRAL (Figure 5.31) to be placed in a three-day, elliptical orbit rather than a two-day, elliptical orbit possible with Ariane 5. The total spacecraft mass will be 3.6-3.8 metric tons, depending upon the launch vehicle utilized, with a science payload of 1.9 metric tons. The two solar arrays will furnish up to 1.3 kW of which 0.6 kW will be available for the payload. The general dimensions of the spacecraft will be 3 m in diameter and 4 m in height (References 247-251).

As noted in Section 5.3.1, the final round of competition for the next Medium Mission (M3) is already underway. Of the five remaining candidates, two are devoted to astrophysical objectives: COBRAS (Cosmic Background Radiation Satellite) and STARS (Seismic Telescope for Astrophysical Research from Space). The former would examine the universal 2.7° K

background radiation at greater sensitivities than accomplished to date, while the latter would monitor stellar phenomena to learn more about their interior structures. Both proposed spacecraft are of the 1.2-metric-ton class. A final M3 selection is expected in 1996 (References 114-115).

#### 5.4.2 Germany

In addition to its support of ESA astrophysics missions, Germany took the lead in the ROSAT (Roentgensatellit) X-ray imaging telescope program which was a cooperative effort among Germany, the UK, and the US. Under prime contractor Dornier, Germany was responsible for the spacecraft as well as the principal 0.8 m diameter X-ray (6-120 Å) telescope. The UK provided a Wide Field Camera for extreme UV observations in the 60-300 Å band, while the US furnished the High Resolution Imager for the X-ray telescope and launch and spacecraft control services.

ROSAT is a 2.4-metric-ton, 3-axis-stabilized satellite with a length of 4.3 m (Figure 5.32). Designed for an operational life of only 18 months from its June, 1990, launch date, ROSAT was still operational at the end of 1994 and was expected to continue returning valuable scientific data into 1996. ROSAT's orbit has a mean altitude of 550 km at an inclination of 53° (References 252-254).

#### 5.4.3 India

India's launch of SROSS-C (Stretched Rohini Satellite Series) on 20 May 1992 provided the nation with its first astrophysical

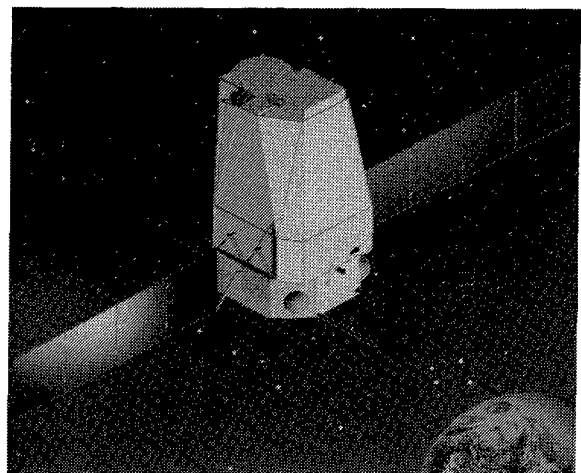


FIGURE 5.31 INTEGRAL PRELIMINARY CONCEPT.

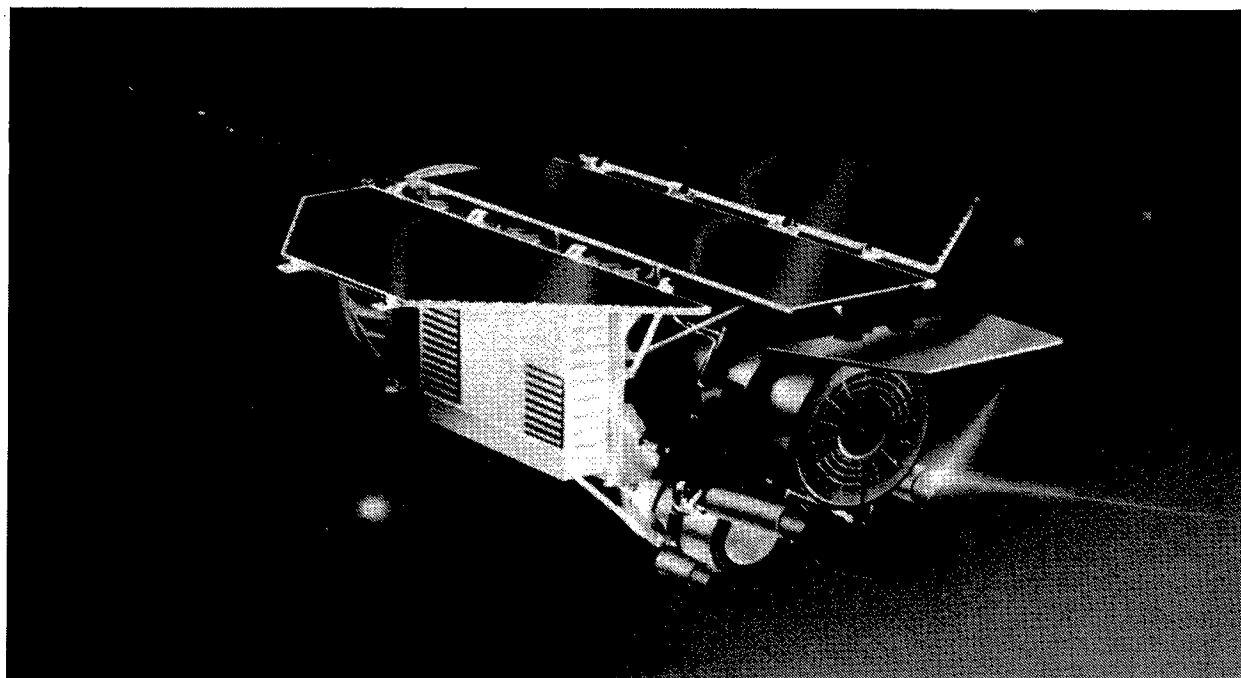


FIGURE 5.32 ROSAT SATELLITE.

observatory, albeit temporarily. The primary purpose of the flight was to test the ASLV launch vehicle which had failed on the two previous attempts. The SROSS-C was a payload of opportunity which carried a geophysics package and a gamma ray burst detector. The latter was tuned to the energy range of 20 keV-3 MeV and consisted of high voltage scintillation detectors. The observational program was concentrated on the southern celestial sky. Unfortunately, the 106-kg spacecraft decayed after only 55 days instead of an anticipated one year due to the less-than-nominal performance of the launch vehicle: an orbit of only 256 km by 435 km was achieved (References 255-257).

A replacement for SROSS-C, SROSS-C2, was successfully launched on 4 May 1994 and inserted into an orbit of 434 km by 921 km at an inclination of 46.0°. The slightly heavier SROSS-C2 (113 kg total mass) was also equipped with a gamma ray burst detector. The new spacecraft also has a modest orbital maneuver capability which was used to lower apogee 300 km in July, 1994 (Reference 258-260).

#### 5.4.4 Italy

Like Germany, Italy is heading an international effort to field a complex X-ray observatory designed to characterize a variety of stellar and galactic objects. The Satellite Astronomic raggi-

X (SAX) program represents a bilateral agreement between Italy and the Netherlands for the launch of a 1.4 metric ton spacecraft by an American commercial Atlas 1 launch vehicle. SAX and Germany's ROSAT were originally conceived as US Space Shuttle payloads, but restructuring of the STS program in the wake of the Challenger accident forced both satellites to expendable vehicles.

Sponsored by the Italian Space Agency and the Dutch Space Research Organization, SAX is being prepared under the prime contractorship of Alenia Spazio with assistance from Fokker. The spacecraft is designed to operate in a 600 km high orbit with a nearly equatorial inclination. The spacecraft will be 2.7 m in diameter and 3.6 m long with two solar arrays (2.6 m by 3.5 m each) capable of producing 2.5 kW of electrical power. The spacecraft is anticipated to be operational for up to four years. A suite of Italian X-ray telescopes and detectors and Dutch Wide Field Cameras will span an energy range of 0.1-300 keV, concentrating on long-term variable sources. During 1992-1994 the program came under attack for both rising costs and technical difficulties. A planned early 1994 launch date was postponed nearly two years (References 261-264).

Under consideration, in conjunction with the US, is a small ultraviolet astronomical platform. The 300-kg class JUNO satellite would be

developed by Alenia Spazio under sponsorship of the Italian Space Agency and would carry scientific instruments furnished by NASA. No formal program has yet been approved, and a launch is unlikely before the end of the decade (Reference 56).

#### 5.4.5 Japan

To date all Japanese astrophysics spacecraft have been developed under the auspices of the Institute of Space and Aeronautical Science and consequently have been modest in size in order to be accommodated by the M-3 class of launch vehicles (Section 2.6). However, the four principal spacecraft, all devoted to X-ray astronomy, have been eminently successful: Corsa-B (Hakucho) in 1979, Astro-B (Tenma) in 1983, Astro-C (Ginga) in 1987, and Astro-D (Asuka) in 1993. The Astro-C mission was completed in November, 1991 and was followed 15 months later by Astro-D on 20 February 1993.

Astro-D is a 420 kg spacecraft operating in LEO at a mean altitude of less than 600 km for a period of 5-6 years. With a 1.3 m diameter and a 4.7 m length (after telescope extension in orbit), Astro-D (Figure 5.33) is an order of mag-

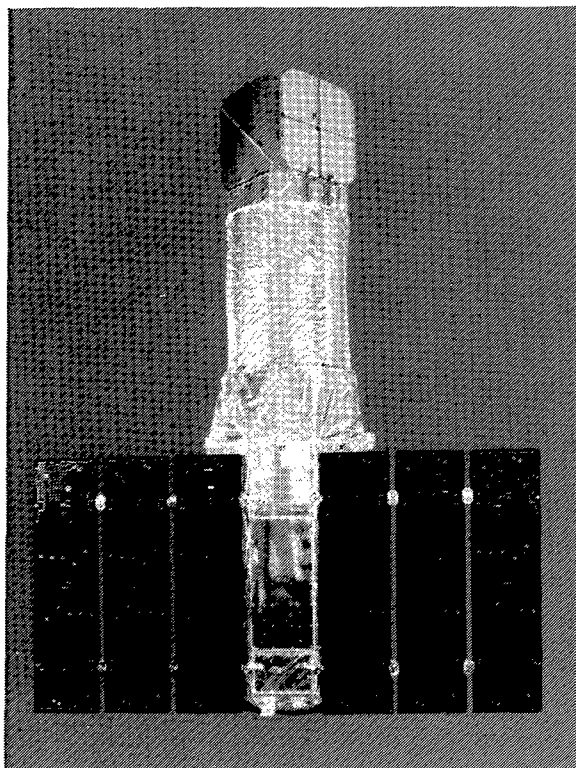


FIGURE 5.33 ASTRO-D (ASUKA) SATELLITE.

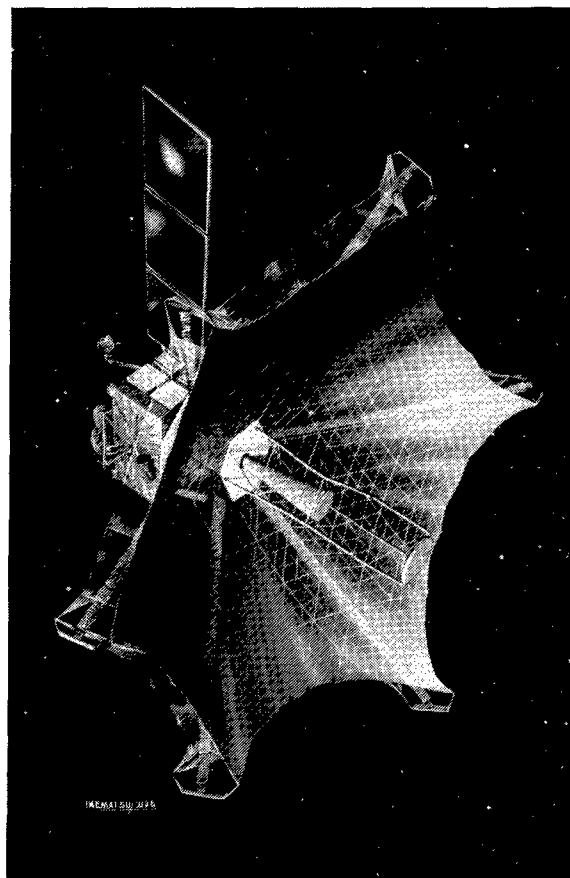


FIGURE 5.34 MUSES-B SATELLITE.

nitude more sensitive than its predecessor and will scan the electromagnetic spectrum from 1 to 12 keV. The principal instruments are an American-supplied X-ray telescope with a CCD camera and a Japanese imaging gas scintillation proportional counter, sensitive to x-rays in the 0.5-10.0 eV range. The solar arrays provide up to 0.6 kW for the mission which is expected to last through 1996 (References 265-271). Astro-E is scheduled for launch in 1999 to continue Japan's X-ray observations, again with an American sensor on board (References 272-273).

In 1996 with the help of ISAS' new M-5 launch vehicle, the institute plans to expand its astrophysical studies into the radio spectrum with the Muses-B spacecraft. The objective of the new VLBI Space Observatory Program (VSOP) is to obtain quality images of both highly energetic and weak radio sources at frequencies of 1.6, 5, and 22 GHz. The 800-kg spacecraft (Figure 5.34) will deploy a 8-m diameter, gold-plated mesh antenna once it reaches an operational orbit of 1,000 km by 20,000 km. The primary contractors developing Muses-B

are Mitsubishi Electric Company and Heavy Industries, Nippon Electric Company, Sumitomo Heavy Industries, and Toshiba Corporation (References 265, 273-274).

#### 5.4.6 Russian Federation

Thirty years of deep-space astrophysical investigations from Soviet unmanned orbital observatories came to an end in 1994 with the shutdown of the last such satellite. No similar spacecraft have been launched since the dissolution of the Soviet Union, and the spacecraft under development at that time have been delayed repeatedly as budgetary difficulties have grown. With a backlog of four major space observatories, proposals for new programs have been afforded little serious attention and no commitments.

The Granat X-ray and gamma-ray observatory was launched 1 December 1989 by a Proton booster into a highly elliptical, 4-day orbit of 1,760 km by 202,480 km with an initial inclination of 51.9°. During Granat's nearly 5-year active life, its orbit was perturbed by solar-lunar perturbations, drastically increasing the inclination and reducing the eccentricity (Reference 275). By the end of operations in September, 1994, the orbital parameters were 59,025 km by 144,550 km and an inclination of 86.7°.

Granat was the last of the Venera-class spacecraft produced by the Lavochkin Scientific Production Association and was similar to the Astron observatory which was functional during

1983-1989. The 4.4 metric ton Granat carried a multi-national scientific payload of almost 2.3 metric tons and stood 6.5 m tall with a total span across its solar arrays of 8.5 m (Figure 5.35). Power provided by the 3-axis-stabilized spacecraft to the payload was approximately 400 W.

The major instrument on Granat was the French-built, one-metric-ton Sigma gamma ray telescope designed to detect energy in the 30 keV to 2 MeV band with a 7° by 7° field-of-view. Adjacent to Sigma on one side were four Soviet ART-P imaging X-ray telescopes created by the Institute of Space Research and in particular its Frunze Special Design Bureau. The ART-P telescope covered the energy range of 3-100 keV with a narrow 1.8° by 1.8° field-of-view. On the other side of Sigma were four ART-S spectral X-ray telescopes designed by the same team which built the ART-P and covering the same energy regime with a 2° by 2° field-of-view. The Frunze Special Design Bureau also provided the Podsolnukh installation consisting of an X-ray telescope (2-25 keV, 2.5° by 2.5° FOV) mounted on a rapidly moving platform which is aimed after being cued by the Konus-B all-sky, gamma-ray burst detector provided by the Leningrad Physical-Technical Institute. Rounding out the deep space payload suite were the French Phoebus spectrometer (200 keV-40 MeV) and the Danish Watch X-ray burst detector (5-150 keV), both of which were all-sky instruments (References 276-279).

Granat was caught in two ways by the fall of the USSR. First, the main spacecraft control center was located at Ukraine's Yevpatoriya facility in the Crimea region where data collection and spacecraft operations were accomplished via a 70-m diameter dish antenna. The newly declared independence of Ukraine, coupled with the historical close ties of the Crimea to the Russian Federation, introduced new political obstacles. The most significant problem, however, was in financing the ongoing mission. The French space agency, with its substantial investment in Granat, directly subsidized continuing operations. The benefit was clear in the scientific discoveries of the spacecraft (References 280-286).

Replacing the Venera-class platform used by Granat will be the new Spektr-class series of high altitude astrophysical observatories. Built by the Lavochkin NPO, the Spektr spacecraft bus will support up to four major missions in the

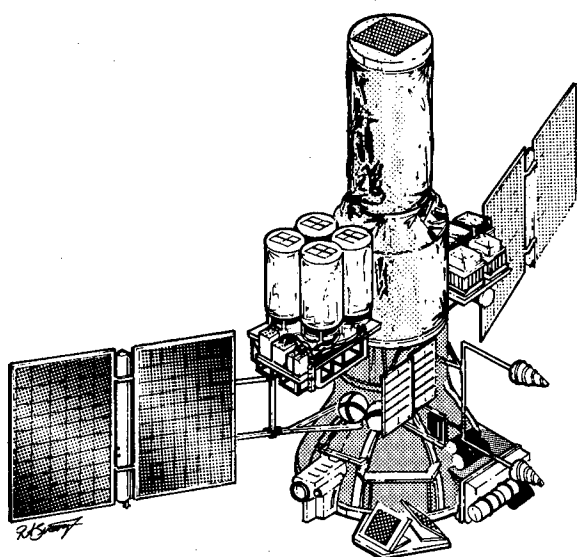


FIGURE 5.35 GRANAT SATELLITE.

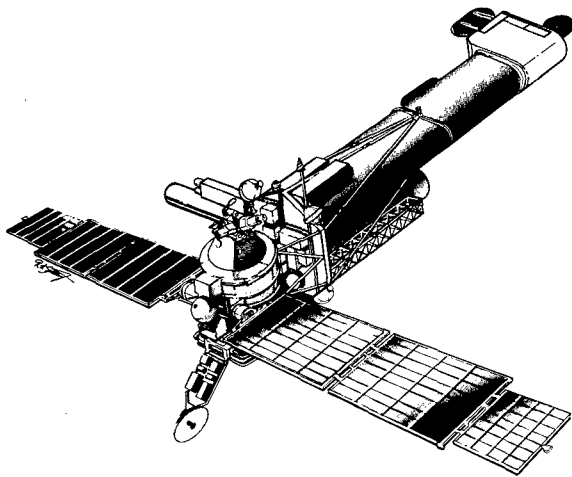


FIGURE 5.36 SPEKTR-X $\gamma$  SATELLITE.

1990's and beyond: Spektr -X $\gamma$  for X-ray and gamma ray astronomy, Spektr-R for radio astronomy, Spektr-UVT for ultraviolet observations, and Spektr-IR for infrared investigations. The 3.5 metric-ton, 3-axis-stabilized Spektr bus will measure more than 18 m across its solar arrays which provide 3 kW of electrical power at beginning of life including up to 0.8 kW for the scientific payload. The attitude control system is designed for an operational pointing accuracy of not worse than 4 arcminutes, and the spacecraft projected lifetime is three years. The maximum scientific payload for Spektr will be approximately 2.5 metric tons for a total 6-metric-ton spacecraft mass (References 287-288).

The first Spektr satellite to be launched will be Spektr-X $\gamma$  currently scheduled for 1996 (Figure 5.36). The Proton launch vehicle will insert the spacecraft into a highly elliptical orbit with a perigee near 2,000 km and an apogee of 200,000 km, resulting in a 4-day orbital period similar to that of Granat. Originally conceived and sponsored by the USSR/CIS Institute of Space Research, Spektr-X $\gamma$  now boasts wide cooperation from 20 international participants, including the former Czechoslovakia, Denmark, ESA, Finland, Germany, Israel, Italy, Japan, Turkey, the UK, and the US.

The principal scientific instrument will be the SODART grazing incidence X-ray telescope assembly with two parallel telescopes operating in the 0.3-20 keV regime. The approximately 1.5 metric ton unit offers nine focal instruments, including a polarimeter, a gas scintillation pro-

portional counter, a spectrometer, and four (two per telescope) XSPECT position-sensitive proportional counters. Also part of the scientific package will be the JET-X (Joint European X-ray Telescope) X-ray telescope (0.1-10 keV), the MART X-ray telescope (4-100 keV), the EUVITA UV telescope (0.07 keV), the MOXE X-ray burst detector (3-12 keV), and the SPIN gamma ray burst detector (10 keV-MeV). The total spacecraft will be approximately 5.6 metric tons, including the 2.8 metric ton payload (References 289-293).

Although more than four years behind schedule, Spektr-X $\gamma$  did make steady progress during 1993-1994, both technically and financially. Most engineering tests were successfully completed, and activities shifted to the manufacture and integration of flight hardware. The success of Spektr-X $\gamma$  may well decide the fate of her sister spacecraft (References 294-297).

Tentatively scheduled for launch the year after Spektr-X $\gamma$ , is Spektr-R, also known as Radioastron, with an objective of establishing a Very Long Baseline Interferometer (VLBI) between the spacecraft and large radio telescopes on Earth. Spektr-R will carry a 10-m diameter radio telescope tuned to receive frequencies of 0.3, 1.6, 5.0, and 22 GHz (Figure 5.37) in a highly elliptical, 28-hr Earth orbit. The

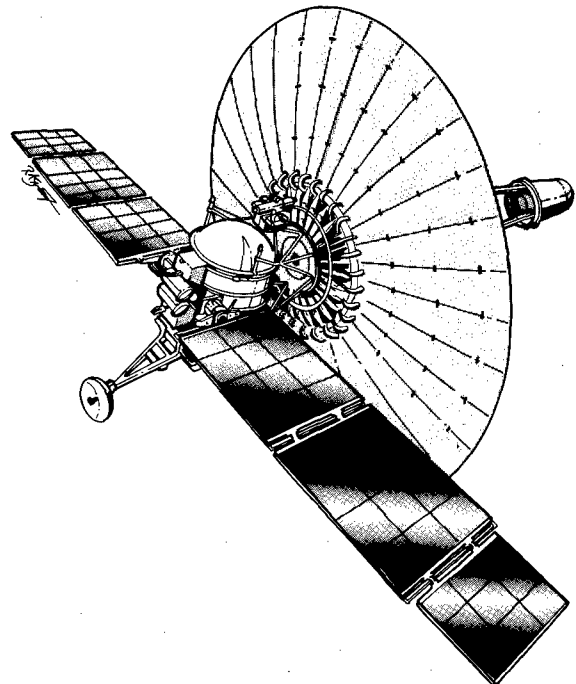


FIGURE 5.37 SPEKTR-R SATELLITE.



Ukrainian Yevpatoriya Deep Space Tracking Center with its 70-m diameter radio telescope will serve as the primary spacecraft control facility, while smaller 25-m and 32-m antennas in the former USSR will assist with spacecraft communications and 70-m antennas at Ussuriysk and in Uzbekistan will become part of the VLBI. The US Deep Space Network will also play a major role in satellite tracking and data collection.

The scientific payload mass will amount to about 1.5 metric tons, including the 700-kg deployable antenna. Early plans for a more ambitious Radioastron program involving six spacecraft over a period of 15 years have at least temporarily been shelved. The launch of Spektr-R, once envisioned as early as 1991, is now set for 1997 (References 298-307).

Near the end of the decade the Spektr-UVT spacecraft is tentatively scheduled for launch into a 500 km by 300,000 km orbit with an inclination of  $51.5^\circ$ . However, within eight months the perigee will be raised to 40,000 km for the remainder of the 3-year mission. The principal participants in the project are now Canada, Germany, Italy, Russia, and Ukraine with Russia's Institute of Astronomy assuming a lead position. The purpose of the mission is to perform UV (including EUV and XUV) observations with a higher fidelity than those of Astron.

The centerpiece instrument for Spektr-UVT will be the T-170 Ritchey-Chretien telescope (912-3,600Å) consisting of a 170 cm (light) diameter primary mirror and a 49 cm (light) diameter mirror in a main housing more than 8 m in length and 2 m in diameter (Figure 5.38).

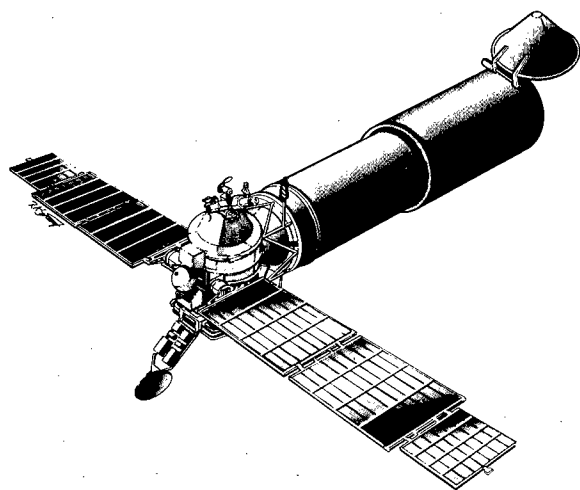


FIGURE 5.38 SPEKTR-UVT SATELLITE.

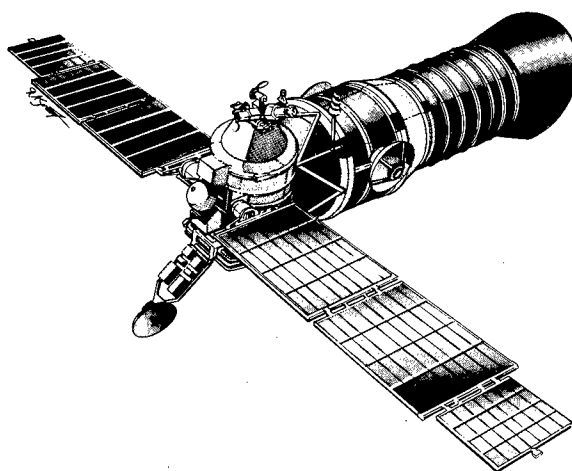


FIGURE 5.39 SPEKTR-IR SATELLITE.

The three major focal plane devices are (1) a high resolution dual Echelle spectrograph (1150-3600Å), (2) a medium and low resolution (912-1,200Å and 1,150-3600Å, respectively) Rowland spectrograph, and (3) a direct imaging camera (912-3600Å). Under consideration is the addition of two T-50 (50 cm diameter) and four T-20 (20 cm diameter) EUV/XUV telescopes. One T-50 (T-50I) would be used for direct imaging (400-800Å), whereas the other T-50 (T-50S) would be equipped with a low resolution spectrograph (400-1,200Å). The T-20 telescopes would permit narrow band imaging within the range of 100-300Å (Reference 288).

The fourth and least mature proposed Spektr mission is Spektr-IR, which may not be flown until after the end of the decade (Figure 5.39). Seriously examined since 1986 (originally under the name Aelita), this infrared observatory would carry a 1-m diameter, cryogenically cooled telescope operating in the 0.15-2 mm band for studies of interstellar and intergalactic dust and molecular clouds as well as the general background environment. Liquid neon and super fluid helium may be used to lower the temperature of the telescope to  $27^\circ$  K and of the photometer to  $1.8^\circ$  K, respectively (References 308-309).

Of special interest to astrophysicists is the precise nature, including anisotropy, of the universal background radiation ( $\sim 2.7^\circ$  K) at 37 GHz. In 1983-1984 the Prognoz 9 spacecraft carried out the Relikt experiment from a unique Earth orbit of 400 km by 720,000 km in an attempt to characterize the uniformity of emissions around the celestial sphere. However,

despite the spacecraft's extreme apogee (twice the distance to the Moon), interference from the Earth and Moon as well as spacecraft systems degraded the quality of the observations.

While data from Prognoz 9 was still being reduced nearly 10 years later, final preparations were underway for the Relikt-2 experiment. In addition to employing instruments with significantly greater sensitivity than the first mission, Relikt-2 will be performed far away from the Earth-Moon system around the L2 libration point about 1.5 million km from the Earth on the side opposite the Sun. The Relikt-2 satellite, which will be based on the Prognoz-M2 spacecraft bus (Section 5.2.7), is scheduled for launch about 1996 after which it will conduct a close fly-by of the Moon on its third revolution in an extremely elliptical Earth orbit for a gravitational assist toward L2 (Figure 5.40). Once the vehicle reaches its destination, a halo orbit around L2 will be established with an orbital period of 180 days (References 309-314).

Under serious development since 1986 in the Institute of Space Research, the Relikt-2 instrument suite now includes five separate radiometers operating at a wavelength of 1.5 mm, 3.0 mm, 5.0 mm, 8.0 mm, and 13.5 mm, respectively. Each radiometer will operate through two perpendicular antennas with a 7° beam width: one pointed away from the Sun and the other perpendicular to the spacecraft's spin axis.

One of the oldest problems in astronomy has been the inaccuracy of positional data for the hundreds of thousands of cataloged stars used in cosmological as well as geophysical research. Although star maps have improved considerably during the 20th Century, the inherent limitations of surface-based observations can be overcome from a high altitude space platform. Since 1989 the Sternberg State Astronomical Institute of Moscow University in conjunction with the Lavochkin NPO, the Vavilov State Optics Institute, and the All-Union Television Scientific Research Institute, has been promoting the Lomonosov astrometric project with its goal of creating an ultra-high precision star catalog (References 315-318).

The program's objectives include observations of all stars of 10th magnitude and brighter (~400,000), of selected stars between 10th and 13th magnitude (~8,000), of 30 of the brightest sources of extra-galactic radiation, and of 40 natural bodies of the solar system (major and

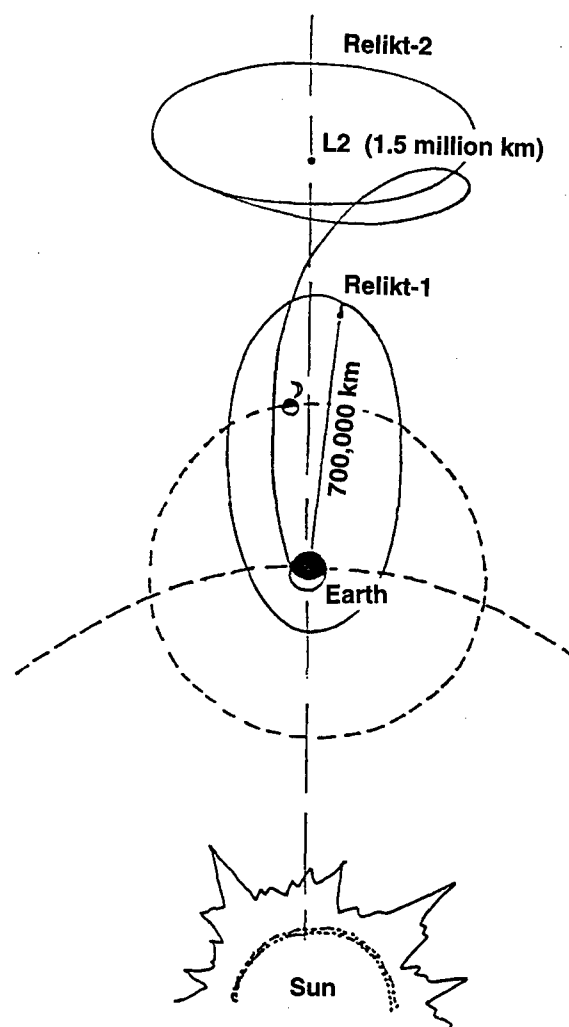


FIGURE 5.40 RELIKT-1 AND RELIKT-2 ORBITS.

minor planets). These observations would be carried out from an orbit about the Earth of 1,500 km by 120,000 km, yielding a 48-hour period of revolution. Actual measurements would be performed during a 32-hour period when the spacecraft is more than 80,000 km above the Earth. The principal data reception facility would be at Medvezhi Oзера in the Moscow region with reserve sites at Yevpatoriya and Ussuriysk.

Based loosely on the Venera-class spacecraft but with improvements developed for the new Spektr-class satellites, Lomonosov is envisioned as a 5.8 metric ton, 9 m tall vehicle with a 1,000 kg scientific payload (Figure 5.41). A complex solar array could produce up to 3 kW

of electrical power. The primary instrument is a Cassegrain telescope with a 1 m diameter main mirror with an equivalent focal length of 50 m. The focal plane detector will be a CCD matrix of 800 x 800 elements. Originally planned for a launch in 1995-1996, this project appears to be searching for funds.

A much more modest alternative to Lomonosov has been proposed under the Regatta-Astro program. As noted in Section 5.2.7, the Regatta series of small spacecraft (<230 kg payloads) are being developed by the Institute of Space Research to perform a variety of space science investigations. The Regatta-Astro mission is specifically designed to conduct astrometric and radiometric observations of stars and other celestial bodies. Unlike Lomonosov, Regatta-Astro would forsake the relative stability of a  $L_2$  halo orbit for a quasi-satellite orbit with an inclination of  $10^\circ$  to the ecliptic and varying ranges from Earth of 2-10 million kilometers. In orbit the approximately 575-kg Regatta spacecraft would exhibit a height of 2.75-3 m and a diameter across the solar sail and solar rudders of 6-9 m (References 319-322).

In early 1991 an operational period for Regatta-Astro of 1994-1997 was proposed, but

the current status of the project is unclear. If successful, a second Regatta-Astro could be flown with more precise observational instrumentation. Plans for similar Regatta missions concentrating on thermal IR ( $2-7\ \mu\text{m}$ ) with a spatial resolution of six minutes and on radiometric mapping in the 1.0, 1.5, and 3.0 mm wavebands with a spatial resolution of at least 0.5 minutes have also been devised. These latter missions would also employ quasi-satellite orbits like Regatta-Astro.

#### 5.4.7 Spain

Spain decided in 1990 to develop a small indigenous satellite capable of performing a variety of scientific and applications missions. Sponsored by the National Institute for Aerospace Technology, the satellite is simply called Minisat and will possess a mass of about 200 kg. Despite its small size ( $\sim 1\text{ m} \times 2\text{ m}$ ) the vehicle will be 3-axis stabilized, will carry deployable solar arrays, and will operate for up to three years. The first mission for Minisat is scheduled for 1996 with a launch by the US Pegasus booster. The orbit will be 600 km high with an inclination of  $28.5^\circ$ , and the spacecraft will be controlled by the Maspalomas ground station. Eventually Minisats may be boosted by an

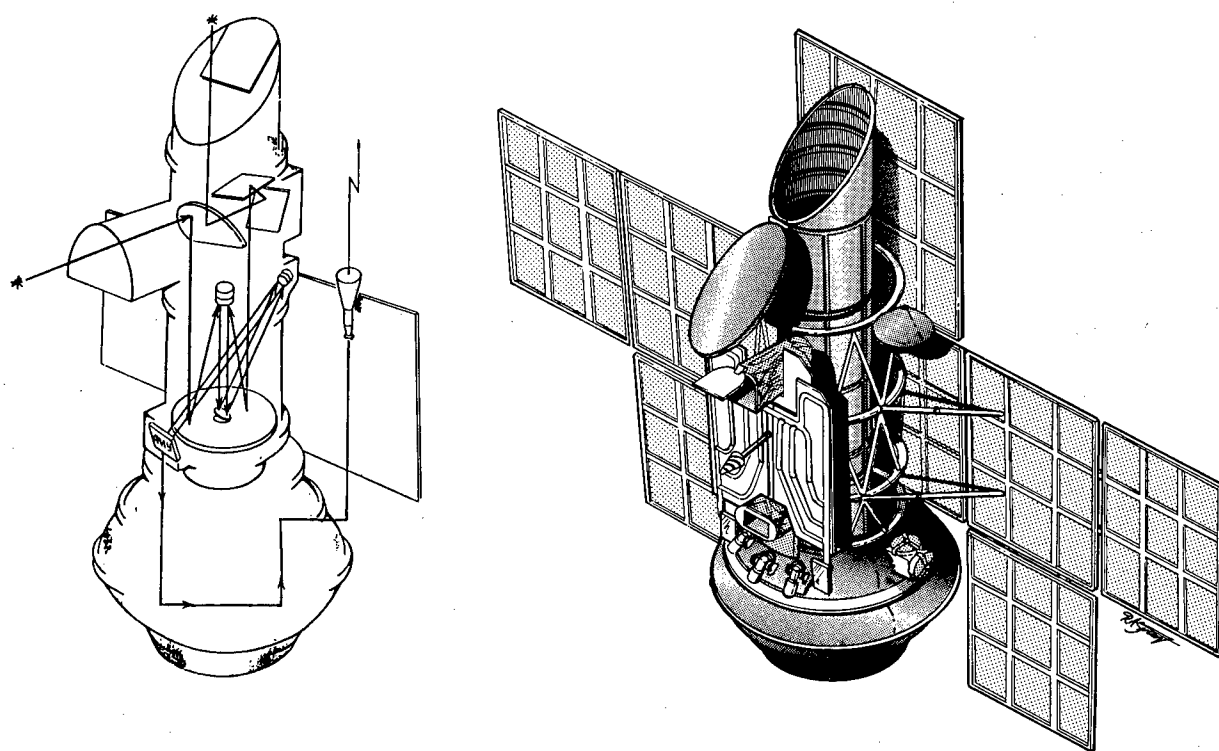


FIGURE 5.41 LOMONOSOV SATELLITE.

upgraded Capricornio launch vehicle also currently under development by Spain. One of the payloads for the maiden Minisat mission is an extreme ultraviolet telescope for astrophysical studies. Other mini-observatories are being considered for subsequent flights (References 323-326).

#### **5.4.8 Sweden**

Following the successes of its Viking and Freja geophysical satellites, Sweden plans to launch a dual-mission satellite in 1997 with the

cooperation of Canada, France, and Finland. The Odin spacecraft will carry radiometers and spectrometers for investigations of celestial objects as well as the Earth's atmosphere. Launched by a Russian Start-1 booster, Odin will have a mass of about 200 kg and will be placed in a circular, sun-synchronous orbit at 600 km. The design life of the 3.0-m diameter, 1.8-m high satellite is two years. The spacecraft will be 3-axis stabilized with an electrical power system of at least 300 W (Reference 56).

## References - Section 5

1. Annual Report, European Space Agency, 1990, pp. 69-70, 1991, pp. 64-65; 1992, p. 54; 1994, p. 70.
2. EURECA, ESA BR-16, European Space Agency, 1983.
3. J. R. Asker, "Eureca Will Offer New Capabilities for Extended Microgravity Experiments", Aviation Week and Space Technology, 20 July 1992, p. 46.
4. P.B. de Selding, "Eureca Platform May Be Retired After Retrieval", Space News, 1-7 March 1993, p. 4.
5. Lin Hua-bao and Min Gui-rong, "The Chinese Recoverable Satellite Program", Paper IAF-89-426, 40th Congress of the International Astronautical Federation, October 1989.
6. P. S. Clark, Chinese Space Activity, 1987-1988, Astro Info Service Publications, 1989.
7. J. M. Lenorovitz, "Europeans Show Mission Control Capabilities with Spacelab D1", Aviation Week and Space Technology, 4 November 1985, p. 19.
8. J. M. Lenorovitz, "Spacelab Mission Coordination Achieves Experiment Goals", Aviation Week and Space Technology, 18 November 1985, p. 55.
9. Experiments in Space. The Second German Spacelab Mission D-2, DLR, March 1992.
10. M.H. Keller and P.R. Sahm, "The German Spacelab Mission D2: A Scientific and Technological Challenge", Earth Space Review, Vol. 3, No. 1, 1994, pp. 11-21.
11. R. Schuiling, "Columbia Reaches '100th Day in Space': Shuttle Program Closes Up 'One Year in Space' ", Spaceflight, July 1993, pp. 232-236.
12. Tokyo Broadcasting System, 15 March 1990.
13. "Japanese Spacelab Mission Extended for More Science", Aviation Week and Space Technology, 21 September 1992, p. 24.
14. "Spacelab Mission Ends", Aviation Week and Space Technology, 28 September 1992, p. 30.
15. Space in Japan: 1988-89, Research and Development Bureau, Science and Technology Agency, 1988.
16. T. Siencko, "Microgravity and Japan", Space, November-December 1990, p. 36.
17. "First Japanese Reusable Spacecraft to Carry Science, Technology Payload", Aviation Week and Space Technology, 20 August 1990, p.70.
18. "Flying into Outer Space", Beijing Guangming Ribad, 20 September 1984.
19. A. Dupas, "Asia in Space: The Awakening of China and Japan", Space Policy, February 1988, p. 31.

20. Aviation Week and Space Technology, 15 October 1990, p. 13.
21. Beijing Television Service, 6 October 1990.
22. Beijing Television Service 14 October 1990.
23. Xinhua Domestic Service.
24. Xinhua News Service, 6 January 1993.
25. G. E. Wukelic, ed, Handbook of Soviet Space Science Research, Gordon and Breach Science Publishers, 1968.
26. G. P. Anshakov et al, "Earth Resources and Research Automated Spacecraft", Photon Design Bureau, 1989.
27. Sotsialisticheskaya Industriya, 8 February 1976.
28. Soviet Space Programs, 1971-1975. Volume 1. Overview, Facilities and Hardware, Manned and Unmanned Flight Programs, Bioastronautics, Civil and Military Applications, Projections of Future Plans, Committee on Aeronautical and Space Sciences, United States Senate, 30 August 1976, p. 222.
29. R. Spangenburg and D. Moser, "An Astronautical Ark", Ad Astra, September 1989, p. 35.
30. Craig Covault, "Soviet Biological Satellite Misses Target by 2,000 Miles", Aviation Week and Space Technology, 19 October 1987, p. 32.
31. Sotsialisticheskaya Industriya, 19 November 1989, p. 4.
32. "Biokosmos-9 - The First Results", Spaceflight, December 1990, p. 380.
33. P. B. de Selding, "Bion-10 Tests Effects of Weightlessness, Radiation", Space News, 4-10 January 1993, p. 4.
34. P. B. de Selding, "Bion-10 Forced to Land When Temperatures Skyrocket", Space News, 25-31 January 1993, p. 12.
35. Komsomolskaya Pravda, 21 January 1993, p.2.
36. ITAR-TASS News Agency, 18 January 1993.
37. ITAR-TASS News Agency, 11 November 1994.
38. "Soviets Developing Advanced Materials Processing Satellite", Aerospace Daily, 19 May 1989, p. 294.
39. The Nika-T, Glavkosmos, 1986.
40. Radio Russia, 3 June 1994.

41. Cluster, technical brochure distributed by ESA, undated.
42. "Cluster Progress", Space, November-December 1994, p. 26.
43. ESA's Report to the 28th COSPAR Meeting, SP-1124, ESA, June 1990, pp. 61-67.
44. All About the European Space Agency, ESA, May 1994, pp. 4-5.
45. Annual Report, ESA, 1993, pp. 31-32 and 1994, pp. 25-26.
46. P.B. de Selding, "Three Major Missions Spark Space Science", Space News, 31 October - 6 November 1994, p. 8.
47. European Space - On Course for the 21st Century, ESA BR-39, ESA, 1987, pp. 17-20.
48. F. Frisch, "Germans Anxious for Launch of Mini-satellite", Spacewatch, October 1993, pp. 12, 14.
49. "NASA Seeking Motor for German Satellite", Space News, 20-26 February 1995, p. 2.
50. J. R. Asker, "Atlantis to Evaluate Characteristics of Tethered Satellite", Aviation Week and Space Technology, 20 July 1992, p. 40.
51. J. R. Asker, "NASA/Martin Marietta to Prove Failure of Atlantis Tethered Satellite Deployer", Aviation Week and Space Technology, 10 August 1992, p. 60.
52. "Inadequate Tests Cause Tether Woes", Aviation Week and Space Technology, 16 November 1992, p. 65.
53. A. Lawler, "Tether Reflight Included in Goldin Spending Plan", Space News, 13-19 December 1993, pp. 3, 29.
54. L. Tucci, "Scientists Ready for Second Round With Tethered Satellite", Space News, 17-23 January 1994, p. 8.
55. "Tethered Satellite System Set for Shuttle Reflight", Space News, 21-27 March 1994, p. 12.
56. T. Pirard, "Small is Beautiful", Spaceflight, April 1995, pp. 122-124.
57. The Institute of Space and Astronautical Science, 1993, Ministry of Education, Science and Culture, undated, pp. 14-15.
58. "New Japanese Spacecraft to Study Solar Flares, Effects of Sun on Earth", Aviation Week and Space Technology, 27 August 1990, pp. 76-81.
59. J.R. Asker, "Japan/U.S. Geotail Mission Set for NASA's First Commercial Launch", Aviation Week and Space Technology, 20 July 1992, pp. 64-65.
60. N.W. Davis, "Japan's ISAS Pursues 'Independent' Agenda", Aerospace America, July 1993, pp. 13-15.

61. Zhu Yilin, "Small Satellites in China", Earth Space Review, Vol. 2, No. 3, pp. 20-24.
62. Europe and Asia in Space 1991-1992, pp. 200-201.
63. Yu. Gordeyev, Moskovskiy Komsomolets, 7 October 1984, p. 4.
64. Sotsialisticheskaya Industriya, 28 November 1987, p. 2 and 10 November 1988, p. 4.
65. A. Meistera and S. Gorkina, Aviatsiya i Kosmonavtika, August 1993.
66. "Canadian Experiment for Soviet Mission", Spaceflight, February 1988, p. 53.
67. V. Ovcharov, Krasnaya Zvezda, 19 December 1986, p. 4.
68. T. Breus, Aviatsiya i Kosmonavtika, September 1984, p. 39.
69. I.A. Strukov, et al, Pisma V. Astronomicheskiiy, May 1992, pp. 387-395.
70. Kosmicheskiiye Issledovaniya, July-August 1992, pp. 435-454; July-August 1993, pp. 18-37; January-February 1994, pp. 3-35.
71. I.A. Strukov, et al, "Relikt-2 Project: Scientific Program and Structure", Paper IAF-90-421, 41st Congress of the International Astronautical Federation, 1990.
72. "Small Solar Sail Spacecraft for Regatta Project", Zemlya i Vselennaya, January-February 1991, p. 3.
73. G.A. Avanesov, "Small Space Lab - 'Regatta' Project Spacecraft", Pr-1692, Institute of Space Research, 1990.
74. A. Yu. Kogan, "The New Spacecraft 'Regatta' ", Space Bulletin, Vol. 1, No. 1, pp. 8-10, 1993.
75. "Regatta Ready To Sail", Spaceflight, June 1991, p. 191.
76. I. Parker, "Freja Images Aurora", Space, April 1993, pp. 18-19.
77. P.B. de Selding, "European Builders Expect Small Satellite Market Boom", Space News, 11-17 July 1994, p. 16.
78. Advertisement, Space News, 28 February-6 March 1994, p. 10.
79. D.G. Fearn, et al, "The Development Status of the Space Technology Research Vehicle", Paper IAF-91-008, 42nd Congress of the International Astronautical Federation, 1991.
80. P.B. de Selding, "British To Launch Pair of Satellites on Ariane's ASAP in June", Space News, 16-22 May 1994, p. 18.
81. P. Mace, et al, "STRV-1: International Success Study", Aerospace America, October 1995, pp. 28-32.
82. Europe and Asia in Space 1991-1992, pp. 209-210.



83. N. Longdon, "European Rendezvous", Spaceflight, November 1992, p. 366.
84. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 41-45.
85. Annual Report, ESA, 1993, pp. 39-40 and 1994, pp. 37-38.
86. W. Harwood, "Ulysses Begins Survey of Solar Polar Activity", Space News, 11-17 July 1994, p. 18.
87. C. Covault, "Ulysses Exploring South Pole of Sun", Aviation Week and Space Technology, 12 September 1994, pp. 50-51.
88. "Ulysses Probes the Sun's South Pole", Spaceflight, December 1994, pp. 417-418.
89. "Ulysses Finds Differences in Solar Wind at High, Low Latitudes", Spaceflight, September 1995, pp. 304-305.
90. N. Angold, et al, "Ulysses Operations at Jupiter-Planning for the Unknown", ESA Bulletin, No. 72, 1992, pp. 44-51.
91. R.G. Marsden and K.-P. Wenzel, "The Ulysses Jupiter Flyby - The Scientific Results", ESA Bulletin, No. 72, 1992, pp. 52-59.
92. SOHO, technical brochure distributed by ESA, undated.
93. N. Beauclair, "Intespace Teste L'Observatoire Solaire SOHO", Air & Cosmos, 9 December 1994, p. 40.
94. "Lockheed Traces Corona", Space, January-February 1995, p. 26.
95. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 67-73.
96. Annual Report, ESA, 1993, pp. 30-31 and 1994, p. 25.
97. W.I. McLaughlin, "Cassini's Progress", Spaceflight, October 1992, pp. 389-390.
98. "Huygens Award", Aviation Week and Space Technology, 4 October 1993, p. 15.
99. P.B. de Selding, "ESA Plant To Trim Huygens Price as Construction Begins", Space News, 2-8 May 1994, p. 14.
100. B.A. Smith, "Cassini on Track For Integration Tests", Aviation Week and Space Technology, 24 April 1995, pp. 58-59.
101. "La Sonde Huygens Devra Resister A 2,000°C", Air & Cosmos, 2 June 1995, pp. 40-41.
102. Annual Report, ESA, 1993, p. 32 and 1994, p. 27.
103. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 75-82.

104. Annual Report, ESA, 1993, p. 34.
105. Annual Report, ESA, 1994, p. 29.
106. Rosetta Comet Nucleus Sample Return, SCI(87)3, ESA and NASA, December 1987 (historical project reference).
107. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 95-104 (historical project reference).
108. E. Battifoglia, "Whither Rosetta?", Space, August-September 1992, pp. 30-33.
109. C. Covault, "European Scientists Wary of U.S. Cooperation", Aviation Week and Space Technology, 22 March 1993, p. 22.
110. "ESA Approves Rosetta", Space, December 1993, p. 25.
111. M. Williamson, "Rosetta Holds Key To Comet Secrets", Astronomy Now, June 1995, pp. 49-51.
112. Annual Report, ESA, 1994, p. 30.
113. P.B. de Selding, "ESA Gets Plethora of Proposals", Space News, 21-27 June 1993, p. 6.
114. C. Covault, "New ESA Concepts To Advance Exploration", Aviation Week and Space Technology, 2 May 1994, pp. 22-23.
115. P.B. de Selding, "ESA To Narrow Field for Next Medium Science Mission", Space News, 2-8 May 1994, p. 20.
116. "ESA Space Group Narrows Medium Mission Proposals", Space News, 16-22 May 1994, p. 12.
117. L. Tucci, "Astronomers Seek New-Technology Boost for Observatory", Space News, 31 January - 6 February 1994, p. 11.
118. P.B. de Selding, "Scientists Draft ESA Agenda", Space News, 10-16 October 1994, pp. 3, 21.
119. C. Covault, "ESA Weighs Its Options", Aviation Week and Space Technology, 31 October 1994, p. 24.
120. P.B. de Selding, "ESA Seeks Support for International Lunar Exploration", Space News, 13-19 June 1994, p. 15.
121. "Moon Added to Euro Space Agenda", Spaceflight, August 1994, p. 254. (See related articles on pp. 255-256.)
122. C. Covault, "ESA Proposes Mission To Moon's South Pole", Aviation Week and Space Technology, 15 August 1994, pp. 24-25.
123. "Ariane V44 Launches Microsatellites from Four Western Nations into Orbit", Aviation Week and Space Technology, 5 August 1991, p. 61.

124. Press Trust of India, 6 September 1992.
125. All-India Doordarshan Television, 23 September 1992.
126. H.P. Mama, "An Indian Spacecraft to Mercury?", Spaceflight, June 1993, p. 211.
127. The Institute of Space and Astronautical Science, 1993, Ministry of Education, Science and Culture, pp. 10-11, 26.
128. "Japan's Yohkoh Observation Satellite Returns Data on Characteristics, Behavior of Sun", Aviation Week and Space Technology, 16/23 December 1991, p. 63.
129. K. P. Dawson, "Sun-Watchers Praise Early Solar-A Results", Space News, 16-22 December 1991, p. 6.
130. "Lockheed, Japan Discuss Another Solar A Mission", Space News, 30 November - 6 December 1992, p. 14.
131. The Institute of Space and Astronautical Science, 1993, op. cit., pp. 16, 25.
132. "Japanese Satellite Studies Earth's Magnetic Field", Space News, 3-9 February 1992, p. 16.
133. D.L. Burnham, "Hiten Mission Ends", Spaceflight, August 1993, pp. 278-279.
134. "Moonfall at Furnerius for Japanese Satellite", Space, June 1993, p. 34.
135. Kyodo News Service, 12 April 1993.
136. "Japanese Spacecraft Enters Lunar Orbit", Spaceflight, May 1990, p. 157.
137. "Japan Plans Lunar Mission in 1990", Aviation Week and Space Technology, 23 February 1987, p. 63.
138. D. Burnham, "Japan Approves New Moon Mission - Probes to Study Lunar Surface", Spaceflight, July 1991, p. 225.
139. "Japan's ISAS Pursues 'Independent' Agenda", Aerospace America, July 1993, p. 13.
140. The Institute of Space and Astronautical Science, 1993, op. cit., p. 16.
141. D. Burnham, "Return to the Moon?", Spaceflight, November 1991, pp. 370-376.
142. A. Lawler, "Japan's Lunar-A Will Be First Moon Landing Since 1972", Space News, 24-30 October 1994, p. 18.
143. I. Nakatani, et al, "Planet-B: Japanese Mars Mission", Paper IAF-93-Q.3.400, 44th Congress of the International Astronautical Federation, 1993.
144. J. Kawaguchi, et al, "On Making Use of Lunar and Solar Gravity Assists in Lunar-A, Planet-B Missions", Paper IAF-93-A.6.46, 44th Congress of the International Astronautical Federation, 1993.

145. The Institute of Space and Astronautical Science, 1993, op. cit., p. 17.
146. K. P. Dawson, "Japan to Begin Design Work for Mars Exploration Satellite", Space News, 10-16 February 1992, p. 26.
147. "Japanese Mars Mission at Science Milestone", Aviation Week and Space Technology, 12 October 1992, p. 58.
148. "Lowering the Boom on Mars", Signal, June 1993, p. 15.
149. C. Covault, "Japan Readies First Moon Mission Launch As Companies Seek Lunar Base Role", Aviation Week and Space Technology, 8 January 1990, pp. 20-21.
150. A. Lawler, "Japan Plans Lunar Base Study", Space News, 27 August - 2 September 1990, pp. 3, 21.
151. "Japanese To Seek Funds To Study Lunar Helium-3", Space News, 19-25 July 1993, p. 15.
152. "Japan Plans To Launch Helium 3 Lunar Mining Effort in 1995", Space FAX Daily, 24 January 1994, p. 1.
153. Kyodo News Service, 14 June 1994 and 28 May 1995.
154. A. Lawler and S. Mansfield, "Japan Adds Moon to Agenda", Space News, 18-24 July 1994, pp. 1, 28.
155. S. Mansfield, "Japanese Officials Plan Lunar Mission Series", Space News, 5-11 June 1995, p. 4.
156. Space Project, Shimizu Corporation, undated. See also separate Space Project brochure Lunar Base Concept.
157. Xinhua News Agency, 25 October 1992 and 13 January 1995. See also Wen Wei Po (Hong Kong), 1 February 1993, p. 2.
158. Zhu Yilin, "A Recipe To Reach Mars", Space News, 9-15 November 1992, p. 15.
159. The Soviet Programme of Space Exploration for the Period Ending in the Year 2000: Plans, Projects and International Cooperation, Part 2 The Planets and Small Planets of the Solar System, Institute of Space Research, USSR Academy of Sciences, Novosti Press, October 1987.
160. Mars-94 Unmanned Spacecraft Mission To Mars, mission description, USSR Academy of Sciences and GLAVKOSMOS, March 1991 (historical project reference).
161. Novosti Kosmonavтики, 1-14 February 1993, pp. 25-31; 15-28 February 1993, pp. 28-32; 1-14 March 1993, pp. 22-27; and 15-28 March 1993, p. 19.
162. M. Chernyshov, Segodnya, 18 May 1993, p. 7.
163. P.B. de Selding, "Russia: Mars Missions Still on Schedule", Space News, 4-10 January 1993, p. 4, 20.
164. "Russians Commit To Mars 1994 Mission", Aviation Week and Space Technology, 8 February 1993, p. 51.

165. L. Tucci, "NASA Signs Mars 94 Deal", Space News, 12-18 April 1993, p. 10.
166. J.R. Asker, "Mars 94 To Carry Novel U.S. Experiment", Aviation Week and Space Technology, 12 April 1993, p. 53.
167. M. Taverna, "Tous Vers Mars En 1994", Air & Cosmos, 14-20 June 1993, pp. 107-108.
168. "Mars 1994 Hampered", Aviation Week and Space Technology, 30 August 1993, p. 22.
169. Y. Telegin, "Preparing for the Mars-94 Mission", Spaceflight, September 1993, p. 294.
170. P.B. de Selding, "RKA Calls for Help On Mars Mission", Space News, 25-31 October 1993, pp. 1, 18.
171. L. David, "Technical, Budget Woes May Delay Mars Probe", Space News, 15-28 November 1993, pp. 1, 24.
172. M.A. Dornheim, "Russians Press Mars 94, But Risks Still Run High", Aviation Week and Space Technology, 3 January 1994, pp. 22-23.
173. P.B. de Selding, "Ax Hovers Over Russia's Plans for Mars '94", Space News, 25 April - 1 May 1994, pp. 4, 21.
174. "Russians Reveal Delay in Mars '94 Launching", Space News, 2-8 May 1994, p. 2.
175. V. Semiryaga, Segodnya, 12 May 1994, p. 9.
176. "Dual Flight for Mars 96", Aviation Week and Space Technology, 23 May 1994, p. 11.
177. C. Covault, "U.S., Russia Plan New Mars Mission", Aviation Week and Space Technology, 6 June 1994, pp. 24-25.
178. V.I. Moroz, Zemlya I Vselennaya, July-August 1994, pp. 3-16.
179. P.B. de Selding, "Russian Woes Hampering Mars Project", Space News, 19-25 December 1994, pp. 1, 20.
180. Small Martian Rover, technical specification sheet distributed by Institute of Space Research, Babakin Engineering and Research Center, and the Institute of Transport Mechanical Engineering, undated.
181. C. Tarrieu, "Status of the Mars 96 Aerostat Development", Paper IAF-93-Q.3.399, 44th Congress of the International Astronautical Federation, 1993.
182. J. Brochard-Runavot, "The International Management of the Mars 94/96 Mission: The French Space Agency Role", Paper IAF-93-H.3.200, 44th Congress of the International Astronautical Federation, 1993.
183. L. David, "McDonnell Douglas, Russia Team on Rover", Space News, 18-24 January 1993, p. 6.
184. "Mars Rover Control Test Proceeds Despite Video Snafu", Space News, 31 May - 6 June 1993, p. 12.
185. W. Boyer, "Russian Rover Operated Via Inmarsat Satellite", Space News, 6-12 September 1993, p. 6.

186. "Russia Slips Mars 96 to 1998", Aviation Week and Space Technology, 4 April 1994, p. 72.
187. M.A. Dornheim, "Marsokhod Rover Tests New Computer, Arm", Aviation Week and Space Technology, 4 April 1994, p. 71.
188. "Newsmaker Forum", Space News, 4-10 April 1994, p. 30.
189. Yu. Murashko, Sankt-Peterburgskiy Vedomosti, 16 June 1994, pp. 1-2.
190. ITAR-TASS News Agency, 16 September 1994.
191. "CNES Plans Test", Space News, 5-11 December 1994, p. 17.
192. C. Lardier, "Essais Du Robot Martien 'Marsokhod' A Toulouse", Air & Cosmos, 23 December 1994, p. 62.
193. B. Iannotta, "Rover Team Simulates Moon, Mars in Hawaiian Crater", Space News, 27 February - 5 March 1995, p. 10.
194. P.B. de Selding, "Funding Needed To Ensure Mars Mission", Space News, 17-23 April 1995, p. 21.
195. P.B. de Selding, "Planned French Balloon May Be Dropped", Space News, 17-23 April 1995, pp. 1, 20.
196. L. David, "Russia Considers Accompanying U.S. in Pluto Exploration", Space News, 2-8 May 1994, p. 14.
197. "Pluto Flight Considered", Aviation Week and Space Technology, 9 May 1994, p. 27.
198. ITAR-TASS News Agency, 11 May 1994.
199. B. Iannotta, "NASA's JPL Engineers Face Challenge: Price Must Fall for Pluto Plans To Fly", Space News, 23-29 January 1995, p. 18.
200. R.L. Staehle, "Continuer L'Exploration Du Systeme Solaire", Air & Cosmos, 6 January 1995, p. 58.
201. R.L.S. Taylor, "Pluto Mission", Spaceflight, February 1995, p. 69.
202. J.W. Head, et al, "Discovery Venera Surface-Atmosphere Geochemistry Experiments (SAGE) Mission Concept", Paper IAF-93-Q.5.417, 44th Congress of the International Astronautical Federation, 1993.
203. B. Iannotta, "Firms Seeks [sic] NASA Backing for Moon Delivery Service", Space News, 18-24 October 1993, p. 29.
204. M. Chernyshov, Segodnya, 4 November 1993, p. 8.
205. K. Rendel, Sankt-Peterburgskiy Vedomosti, 13 May 1994, p. 5.
206. L. David, "NASA Proposes Russian Rover for Moon Surveyor Mission", Space News, 13-19 June 1994, p. 24.

207. M. Simon, "International Space Enterprises", Spaceflight, July 1994, pp. 237-240.
208. L. David, "Lunar Oxygen Facility Tested Aboard Russian Moon Rover", Space News, 29 August - 4 September 1994, p. 10.
209. A. Bakina, Rabochaya Tribuna, 11 November 1994, p. 4.
210. V. Kamyshev, Gudok, 15 November 1994, p. 4.
211. S. Leskov, Izvestiya, 22 November 1994, p. 5.
212. I. Lisov, Novosti Kosmonavtiki, 26 February - 11 March 1994, pp. 29-32.
213. V. Romanenkova, Segodnya, 3 March 1994, p. 9.
214. ITAR-TASS News Agency, 14 June 1993 and 1-2 March 1994.
215. S. Leskov, Izvestiya, 30 May 1992, p. 1.
216. I. Sobelman, et al, CORONAS Information, publication series, Astrophysical Institute Potsdam.
217. V. Orayevskiy, Pravda, 22 October 1990, p. 6.
218. Ja. Buzashy, et al, Astronomicheskii Zhurnal, June 1992, pp. 537-540.
219. V.I. Dranovski and E.I. Ouharov, "Investigation of High Efficient Solar Energy Concentrators with the Help of the Soviet Automatic Universal Orbital Station (AUOS-SM)", Paper IAF-90-217, 41st Congress of the International Astronautical Federation, 1990.
220. SPAS Mission (Preliminary Announcement), USSR Academy of Sciences' Institute of Space Research, undated.
221. G.A. Avanesov, "Global Information System Using Solar 'Storm' Warning Signals", Proceedings of the International Conference on Satellite Communications ICSC '94, 18-21 October 1994, Vol. 1, pp. 228-231.
222. P.B. de Selding, "ESA Provides Hardware, Expertise", Space News, 29 November - 5 December 1993, p. 10.
223. N. Longdon, "Hipparcos Mission Complete", Spaceflight, November 1993, pp. 390-392.
224. "ESA Ends Hipparcos Mission Aug. 15 After More Than 4 Years", Space Watch, September 1993, p. 7.
225. Annual Report, ESA, 1992, p. 35; 1993, pp. 37-39; and 1994, pp. 33-34.
226. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 27-34.
227. M.A.C. Perryman et al, The Hipparcos Mission, SP-1111, ESA, 1989.
228. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 53-59.

229. ISO. Infrared Space Observatory, technical brochure distributed by ESA, undated.
230. Annual Report, ESA, 1994, pp. 24-25.
231. "ISO Cryogenics Cause Two-Year Launch Delay", Space News, 26 April - 2 May 1993, p. 2.
232. "Dornier Finishes Precision Infrared Detector for ISO", Space News, 11-17 May 1992, p. 16.
233. A. Ducrocq, "Le Programme Infrarouge Denis", Air & Cosmos, 2 December 1994, p. 45.
234. "ISO Sera Lance En Octobre Ou Novembre", Air & Cosmos, 14 July 1995, p. 57.
235. "Infrared Space Observatory", Spaceflight, August 1995, pp. 268-269.
236. All About the European Space Agency, ESA, May 1995, p. 5.
237. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 83-87.
238. Annual Report, ESA, 1994, p. 28.
239. P.B. de Selding, "Improper Practices Drive ESA To Trash Bids", Space News, 18-24 April 1994, pp. 1, 20.
240. P.B. de Selding, "ESA Bid Rejections Stir Geographic Rule Debate", Space News, 25 April - 1 May 1994, pp. 3, 20.
241. "ESA Alleges Collusion", Aviation Week and Space Technology, 2 May 1994, p. 23.
242. "DASA Wins ESA Contract For Large X-Ray Satellite", Aviation Week and Space Technology, 17 October 1994, p. 26.
243. P.B. de Selding, "ESA Selects Deutsche Aerospace for X-Ray Craft", Space News, 24-30 October 1994, p. 6.
244. First, Far Infrared and Submillimeter Space Telescope, BR-69, ESA, July 1990.
245. ESA's Report to the 28th COSPAR Meeting, op. cit., pp. 91-95.
246. Annual Report, ESA, 1994, pp. 29-30.
247. N. Longdon, "INTEGRAL Confirmed as ESA's Next Scientific Mission", Spaceflight, August 1993, pp. 274-275.
248. R. M. Bonnet, "Towards the Selection of ESA's Next Medium-Size Scientific Project (M2)", ESA Bulletin, May 1991, pp. 37-52.
249. P.B. de Selding, "Europe's Integral Spacecraft Books Passage to Orbit on Russian Proton", Space News, 7-13 June 1993, p. 25.



250. "NASA Funding Squeeze Clouds Europe's Integral", Space News, 15-28 November 1993, p. 2.
251. Annual Report, ESA, 1993, p. 33 and 1994, p. 28.
252. DARA Information 1991, DARA, June 1991.
253. "Germans Estimate Rosat Will Keep Working Until '94", Space News, 8-14 March 1993, p. 12.
254. ROSAT Newsletter, published by the U.S. ROSAT Science Data Center, NASA Goddard Space Flight Center.
255. All-India Radio, 28 May 1992.
256. Press Trust of India, 8 July 1992.
257. A. Lawler, "India Succeeds With Third ASLV Launch Attempt", Space News, 25-31 May 1992, p. 6.
258. All-India Radio, 4 and 5 May 1993.
259. V. Raghuvanshi, "India Lofts SROSS", Space News, 9-15 May 1994, p. 14.
260. V. Raghuvanshi, "Scientists Switch On SROSS-C2 Instrument", Space News, 16-22 May 1994, p. 8.
261. R. Riccitiello, "Development Snags Push Back SAX Plans", Space News, 1-7 March 1993, pp. 3, 20.
262. R. Riccitiello, "Committee Probes SAX Funding", Space News, 22 June-5 July 1992, p. 24.
263. "Newsmaker Forum", Space News, 13-19 September 1993, p. 22.
264. "Italian Space Minister OKs Sax X-ray Satellite", Space News, 10-16 January 1994, p. 2.
265. "Japan Developing Advanced Spacecraft For Deep Space X-Ray, Radio Astronomy", Aviation Week and Space Technology, 27 August 1990, pp. 80-81.
266. M. Mecham, "Launch of X-ray Satellite Will Aid Big Bang Studies", Aviation Week and Space Technology, 1 March 1993, p. 21.
267. Kyodo News Service, 20 February and 9 April 1993.
268. N. W. Davis, "Japan's ISAS Pursues 'Independent' Agenda", Aerospace America, July 1993, pp. 13-15.
269. M. Oda and Y. Tanaka, "Japan's Blossoming Space Science", Sky and Telescope, January 1987, pp. 7-11.
270. K.P. Dawson, "Japanese Launch Astro-D, Begin Orbital Tests of Satellite", Space News, 1-7 March 1993, p. 7.
271. The Institute of Space and Astronautical Science 1993, op. cit., pp. 8-9, 26.

272. "AXAF-S Sensor To Fly on Astro-E", Space News, 27 February - 5 March 1995, p. 17.
273. M. Mecham, "Japan Broadens Scope of Science Missions", Aviation Week and Space Technology, 20 March 1995, pp. 59-61.
274. The Institute of Space and Astronautical Science 1993, op. cit. p. 13.
275. Europe and Asia in Space 1991-1992, pp. 215-216.
276. Granat, project description and specification sheet distributed by GLAVKOSMOS, 1989.
277. Sovetskaya Kirgiziya, 19 April 1989, p. 1; 30 January 1990, p. 2; and 9 February 1991, p. 10.
278. Sotsialisticheskaya Industriya, 12 April 1989, p. 4.
279. Pravda, 3 December 1989, p. 6.
280. P. B. de Selding, "France May Pay To Save Russian Ground Station", Space News, 9-15 December 1991, pp. 1, 21.
281. P. B. de Selding, "France Cash Sustains Operation of Granat Observatory", Space News, 7-13 December 1992, pp. 1, 23.
282. P. B. de Selding, "CNES Funds on Slow Path to Russia; Debts Piling Up", Space News, 29 March - 4 April 1993, p. 7.
283. Pisma V Astronomicheskii Zhurnal, February 1991, pp. 99-125 and 135-140; December 1991, pp. 1059-1081; January 1992, pp. 3-45; March 1992, pp. 217-227; April 1992, pp. 291-314; July 1992, pp. 570-578; June 1993, pp. 483-489; August 1993, pp. 675-692; January 1994, pp. 5-6; April 1994, pp. 250-252; and May 1994, pp. 323-358.
284. ITAR-TASS News Agency, 30 July 1993.
285. B. Konovalov, Izvestiya, 11 March 1994, p. 2.
286. "Fin Du Satellite Granat", Air & Cosmos, 30 September 1994, p. 31.
287. V. M. Kovtunenکو, et al, "Spectrum: Unified Spacecraft for Astrophysical Observations", Paper IAF-88-001, 39th Congress of the Astronautical Federation, October 1988.
288. A. A. Boyarchuk and E. G. Tanzi, "The Spectrum-UV Project", Workshop on Space Projects to Probe the Internal Structure of the Sun and Sun-like Stars", November 1991.
289. V. M. Kovtunenکو, et al, "Spectrum-X-Gamma Spacecraft", Paper IAF-89-461, 40th Congress of the International Astronautical Federation, October 1989.
290. Flight International, 4-10 July 1990, p. 35.

291. Moskovskaya Pravda, 10 June 1987, p. 3.
292. ITAR-TASS World Service, 4 and 25 February 1993.
293. Yu. Zaytsev, " 'Spectrum-Roentgen-Gamma' - A New Space Project", Advances of Science and Technology, November 1988, pp. 1-3.
294. ITAR-TASS News Agency, 1 December 1994.
295. "X-Ray Telescope Passes Two Pre-Launch Tests", Aviation Week and Space Technology, 27 September 1993, p. 52.
296. T. Foley and P.B. de Selding, "Spectrum Beating Russian Inflation Odds", Space News, 7-13 February 1993, p. 10.
297. B. Konovalov, Nezavisimaya Gazeta, 1 March 1994, p. 6.
298. Radioastron. Ground-Space Radio Interferometer for Astrophysics, Institute of Space Research, October 1986.
299. V.V. Andreyanov, et al, Soviet Astronautics, September-October 1986, pp. 504-507.
300. Radioastron, Institute of Space Research, 1987.
301. B. Konovalov, Izvestiya, 10 April 1988, p. 2.
302. V. V. Andreyanov, Zemlya I Vselennaya, January-February 1989, pp. 13-17.
303. I. Fejes, "Orbit Determination Accuracy Improvement By Space-VLBI Observables as Tracking Data", IAG General Meeting, August 1989.
304. A. Lawler, "U.S., Soviet Astronomy Cooperation Expanded", Space News, 12-18 March 1990, pp. 1, 21.
305. N. Layevich, NTR Tribuna, January 1990, p. 3.
306. Pravda Vostoka, 5 November 1991, p. 1.
307. V. I. Altunin and K. H. Robinett, "Mission Operations System for Russian Space Very-long-Baseline Interferometry Mission", Paper IAF-92-547, 43rd Congress of the International Astronautical Federation, August-September 1992.
308. G. B. Sholomitskiy, "A Cooled Submillimeter Telescope", Soviet Astronautics, September-October 1986, pp. 867-873.
309. V. S. Avduyevskiy, et al, Zemlya I Vselennaya, July-August 1990, pp. 8-16.
310. Pisma V Astronomicheskii, May 1992, pp. 387-395.

311. Kosmicheskiye Issledovaniya, July-August 1992, pp. 435-454; March-April 1987, pp. 163-185; January-February 1987, pp. 152-154; July-August 1992, pp. 435-454; July-August 1993, pp. 18-37; January-February 1994; pp. 3-35.
312. Krasnaya Zvezda, 19 December 1986, p. 4.
313. J. M. Lenorovitz, "Multinational Cometary Watch Group Plans New Ventures", Aviation Week and Space Technology, 10 November 1986, pp. 28-29.
314. I. A. Strukov, "Relikt-2 Project: Scientific Program and Structure", Paper IAF-90-421, 41st Congress of the International Astronautical Federation, October 1990.
315. Project Lomonosov, Astrometric Space Experiment, project description produced jointly by the four participants, 1989.
316. V. M. Kovtunenکو, et al, "Lomonosov Space Astrometric Mission", Paper IAF-90-422, 41st Congress of the International Astronautical Federation, October 1990.
317. V. V. Nesterov, "The 'Lomonosov' Astrometric Space Project", Zemlya I Vselennaya, March-April 1990, pp. 10-16.
318. TASS International Service, 29 December 1989.
319. G. A. Avanesov, et al, "Small Space Lab - The Regatta Project Spacecraft", Paper IAF-90-431, 41st Congress of the International Astronautical Federation, October 1990.
320. "Regatta Ready To Sail", Spaceflight, June 1991, p. 191.
321. A. Yu. Kogan, "Quasi-Satellite Orbits and Their Applications", Paper IAF-90-307, 41st Congress of the International Astronautical Federation, October 1990.
322. G.A. Avanesov, Zemlya I Vselennaya, January-February 1991, pp. 3-8.
323. P. B. de Selding, "Spain Boosts Space Spending, Plans New Launch Vehicle", Space News, 15-21 June 1992, p. 6.
324. "Spanish Satellite Project Matures", Aviation Week and Space Technology, 21 June 1993, p. 26.
325. P.B. de Selding, "Orbital To Launch Spanish Minisat", Space News, 31 October - 6 November 1994, p. 6.
326. W. Ferster, "Spain's Minisat Launch Awaits Negotiation", Space News, 17-23 April 1995, p. 6.

## 6.0 NATIONAL SECURITY PROGRAMS

Many space systems described in Sections 3-5 contribute to national security either directly or indirectly and on a dedicated, dual use, or ad hoc basis. However, specific national security satellite networks are those which are funded and operated by the armed forces for the primary purpose of performing intelligence gathering, attack warning, direct defensive/offensive space activities, or special functions supporting these missions (Table 6.1). Unlike communications, navigation, or meteorological satellites which can serve a wide range of users, national security spacecraft normally have little applicability to civilian needs. Even a great deal of military photographic reconnaissance is of limited utility for many Earth observation studies due to the narrow fields-of-view employed.

To date, of all the European and Asian satellite operators, only the USSR/CIS has deployed significant national security space systems due to technological as well as economic and political reasons. More than 30% of all new Russian space missions undertaken during 1993-1994 fell within this category. The PRC is believed to use its FSW photographic

satellites in part for military reconnaissance, and France is developing its first dedicated military satellites for both reconnaissance and electronic intelligence. Israel and India may follow suit with their own national security systems, and the Western European Union is evaluating the need for a shared system of spy satellites. Discussions about a common European ballistic missile defense system may lead to a future constellation of missile launch detection satellites, while Japan has also expressed an interest in a space-based warning system.

Contrary to popular opinion, the end of the Cold War has not diminished the need or importance of national security space systems. In fact, with reduced military budgets and forces, many nations are placing an even higher premium on intelligence information obtained via space-based platforms. Moreover, the Persian Gulf War of 1991 reinforced the value of specialized satellites in even localized, conventional conflicts. This realization may prompt nations not only to field new national security space systems but also to develop the means of negating such systems of their opponents.

TABLE 6.1 NATIONAL SECURITY SYSTEMS.

	OPERATIONAL	PLANNED
IMAGE RECONNAISSANCE	FSW (PRC) RESURS-T (RF) YANTAR (RF) KOMETA (RF) 5TH GEN (RF) 6TH GEN (RF) 7TH GEN (RF)	HELIOS (FR, IT, SP) HORUS (FR, GM?)
ELECTRONIC INTELLIGENCE	TSELINA-D (RF) TSELINA-2 (RF) EORSAT (RF)	CERISE (FR) ZENON (FR)
EARLY WARNING	OKO (RF) PROGNOZ (RF)	
SPACE DEFENSE	CO-ORBITAL ASAT ? (RF)	
SUPPORT	ROMB (RF) VEKTOR (RF) YUG (RF)	

FR = FRANCE  
PRC = CHINA

GM = GERMANY  
RF = RUSSIAN FEDERATION

IT = ITALY  
SP = SPAIN

## 6.1 IMAGING RECONNAISSANCE

Photographic reconnaissance (photo recon) satellites represented the first operational use of spacecraft to perform dedicated military support missions. Such systems have become extremely valuable in both peacetime and war. Photo recon satellites have been legitimized in their role of monitoring international arms control treaties and are essential for general intelligence gathering, including the assessment of foreign forces and early indications of the development of future weapon systems. During war, photo recons contribute to order of battle assessments, engagement planning, and battle damage assessments. Although photo recons can currently fly with relative impunity over battlefield areas, they are normally restricted to only 1-2 short-duration, overflights per day and are susceptible to cloud cover, lighting conditions, and battlefield obscurants. Recent technological advances have permitted many of these deficiencies to be overcome with the use of moderate resolution synthetic aperture radars.

The early generation photo recons relied on classical photographic techniques with the physical return of the exposed film to Earth (sometimes a week or more after the photographs of interest were taken) for processing, analysis, and distribution. The moderate-to-high resolutions available via this technique were partially offset by the delay in receiving the desired information. With advances in electronic imaging and data transmission systems, real-time or near-realtime return of reconnaissance data is now possible directly from the photo recon or through a geostationary relay satellite. An added advantage of this more sophisticated method is that it lends itself more readily to rapid computer processing techniques.

Historically, photo recon products have been categorized as low-, medium-, or high-resolution, indicating the relative limitations of distinguishing objects of specific sizes. Moreover, the degree of resolution is normally inversely proportional to the field-of-view, e.g., a high resolution system will typically image a very limited region of the Earth measured in tens of kilometers on a side while a low resolution system will cover a wide area hundreds of kilometers on a side in a single image. Together, they provide complementary data of national security significance.

### 6.1.1 France

As early as 1978 France proposed an international monitoring agency employing satellites under the auspices of the United Nations. Failing to win support from either the US or the USSR, by 1981 France was studying the feasibility of deploying a national reconnaissance spacecraft called SAMRO and derived in large measures from the SPOT Earth observation satellite. The studies evolved into the present Helios program, whose maiden launch by an Ariane 40 booster was postponed from 1994 to 1995 due to disruption of the Ariane schedule following the launch failure of 24 January 1994 (References 1-7).

Funded primarily by the French Delegation Generale pour l'Armement (DGA), Helios is also being financially sponsored by Italy and Spain at a level of approximately 14% and 7%, respectively. Responsibility for the overall space system architecture has been delegated to CNES with Matra Marconi serving as the prime contractor. Major subcontractors include Aerospatiale, Alcatel Espace, Alenia, SEP, and Sodern (References 8-10).

Helios will have a mass of about 2.5 metric tons and will operate in a sun-synchronous orbit at an altitude of 680 km and an inclination of 98°. Outwardly, the spacecraft will closely resemble SPOT 4 with a box-like bus and a five-segment solar array capable of generating 2.5 kW of electrical power. A 3-axis stabilization system and precision pointing accuracy will support the primary multi-spectral CCD imaging system with a resolution of one meter. In early 1994 Aerospatiale delivered the principal imaging payload to Matra Marconi, and, by the end

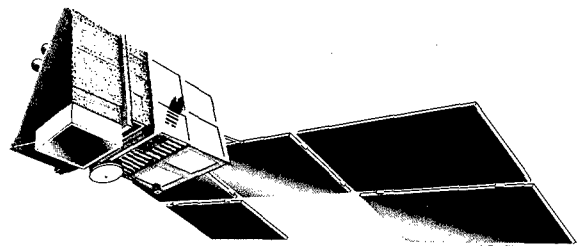


FIGURE 6.1 HELIOS RECONNAISSANCE SPACECRAFT.

of the year, final testing and integration were underway (References 11-12).

The main payload control facility for Helios will be at Creil, France, whereas primary data reception sites will be located in all three partner countries: Colmar, France; Lecce, Italy; and Maspalomas, Canary Islands (Spain). A tiered encryption scheme will restrict images to only one or more of the Helios program states with France having the highest priority and widest data access. Images may also be made available to the Western European Union (Section 6.1.6) or to selected civilian customers on a commercial basis (References 13-15).

The launch of Helios 1A in 1995 is scheduled to be followed by Helios 1B in late 1996 or early 1997. This is a significant change in the original program which envisioned Helios 1B being held in reserve in the case of difficulties with Helios 1A, which has a design lifetime of four years or more. In part, this operational rethinking was brought about by the demonstrated utility of space systems during the Persian Gulf War. Helios-class satellites may also be sold to other nations if France can maintain control of the sale and use of the reconnaissance products (References 16-18).

A pair of Helios 2 spacecraft will be developed for missions beginning in 2001 with improved optical imagers (resolution perhaps down to 0.5 m), new infrared sensors for nighttime reconnaissance, and expanded tape recorder capacities for storage of a greater number of photographs (up to 200) between downlink opportunities. During 1994, Germany was being wooed to join the Helios 2 program as Spain and then Italy threatened to reduce their contributions. The price for German participation was likely to be leadership of the follow-on synthetic aperture radar reconnaissance satellite Horus (formerly known as Osiris) which could be launched as early as 2005. A decision on the Helios 2 and Horus programs was deferred until 1995 after the French national elections (References 16-32).

#### **6.1.2 Italy**

As noted in the previous section, Italy is a founding partner (14% share) in the Helios 1 program and, despite severe financial pressures, anticipates to continue with Helios 2. A data reception and processing center for Helios images has been constructed at Lecce. Alenia is a principal contractor for Helios ground stations.

#### **6.1.3 Japan**

In 1994 Japan began serious consideration of redefining its long-held policy prohibiting the use of space for military purposes. The Japanese Defense Agency, Japan's Space Activities Commission, and the non-governmental Defense Research Center all issued findings that non-lethal, particularly photographic reconnaissance, military space missions were a logical extension of Japan's space and national defense activities. Japan currently operates the JERS spacecraft (Section 4.3.7) with optical and synthetic aperture radar sensors yielding 18 m resolution, a militarily useful capability.

Should national policy be modified to allow military photographic reconnaissance systems, Japanese officials would decide whether to develop domestic spacecraft, procure a foreign space system, or merely purchase high resolution imagery products from commercial vendors. One proposal recommends a network of up to three Japanese spacecraft with resolutions of at least 5 m soon after the turn of the century (References 33-36).

#### **6.1.4 People's Republic of China**

The PRC has been conducting space-based imaging of the Earth since 1975 (Section 4.3). Although some of these missions may have been in whole or in part related to civil requirements, Western assessments have long held that some, if not all, were also concerned with photographic reconnaissance of a national security nature. By the end of 1994 a total of 16 FSW-class spacecraft had been orbited with 15 successful recoveries.

Currently operational are the FSW-1 (1987) series of spacecraft with a demonstrated operational period of up to eight days and the FSW-2 (1992) series of spacecraft capable of stays of up to 16 days in length. FSW satellites are normally flown only once each year and usually in the August-October period. During 1993-1994, one FSW-1 and one FSW-2 were launched on 8 October 1993 and 3 July 1994, respectively. The 1993 mission failed when an attitude control error occurred immediately before the re-entry burn was initiated. Consequently, the return capsule was transferred to a higher elliptical orbit from which natural decay was expected to take two or more years.

Unlike Russian photo recon satellites, FSW-1 spacecraft do not perform orbital maneuvers to adjust their groundtracks for prolonged observations over areas of high interest. Typical

FSW-1 orbital parameters of 210 km by 310 km at inclinations of 57-63° would permit high resolution photography, but the acknowledged sensors are only capable of 10-15 m resolution (film return) or 50 m resolution (digital transmission).

Only two FSW-2 missions had been flown to the end of 1994: 9-25 August 1992 and 3-18 July 1994. The FSW-2 has a greater payload capacity, but details about sensor resolution limits have not been revealed. In addition to exhibiting lower perigees (170-175 km), both of the FSW-2 spacecraft demonstrated small maneuver capabilities during their missions. These attributes would increase the military utility of the vehicles; however, to date no significant photo recon program for national security objectives appears to be underway (See Section 4.3.9 for further technical specifications and characteristics of the FSW-1 and the FSW-2).

#### 6.1.5 Russian Federation

Between 1962 and 1994 the USSR/Russian Federation placed more than 800 photo reconnaissance spacecraft into Earth orbit on dedicated military missions (another 25 spacecraft were lost in launch failures). These missions have ranged in length from only a few days to more than 400 days, a record set by Kosmos 2267 in 1994. Only seven dedicated military photo recons were launched during each of 1993 and 1994. However, on average more

than two spacecraft were operational during the entire period, and no observation gaps appeared (Figure 6.2). Declassified photographs with resolutions of 2-30 m can now be purchased commercially, while resolutions on the order of one-third meter have been acknowledged.

Since the first Soviet photo spacecraft was successfully orbited (Kosmos 4 in 1962), a variety of specialized spacecraft have been developed. Today, four basic classes of the 6-7 metric-ton photo recons are operational, and a possible new generation spacecraft began flight testing in the second half of 1994 (Figure 6.3). All such spacecraft are now launched by the Soyuz-U/U2 launch vehicle from either the Baikonur or Plesetsk Cosmodromes. Whereas most spacecraft physically return film to Earth for development and processing, some, longer duration spacecraft possess either digital transmission or dual transmission/capsule capabilities.

Unlike many satellites designed to photograph the Earth, Russian photo recons fly in posigrade (normally 63°-83°) orbits rather than sun-synchronous trajectories. Consequently, when altitude restoration maneuvers are made every 7-10 days, the satellite's argument of perigee is normally adjusted to keep perigee phased with acceptable lighting conditions. For example, during a typical 2-month mission, the

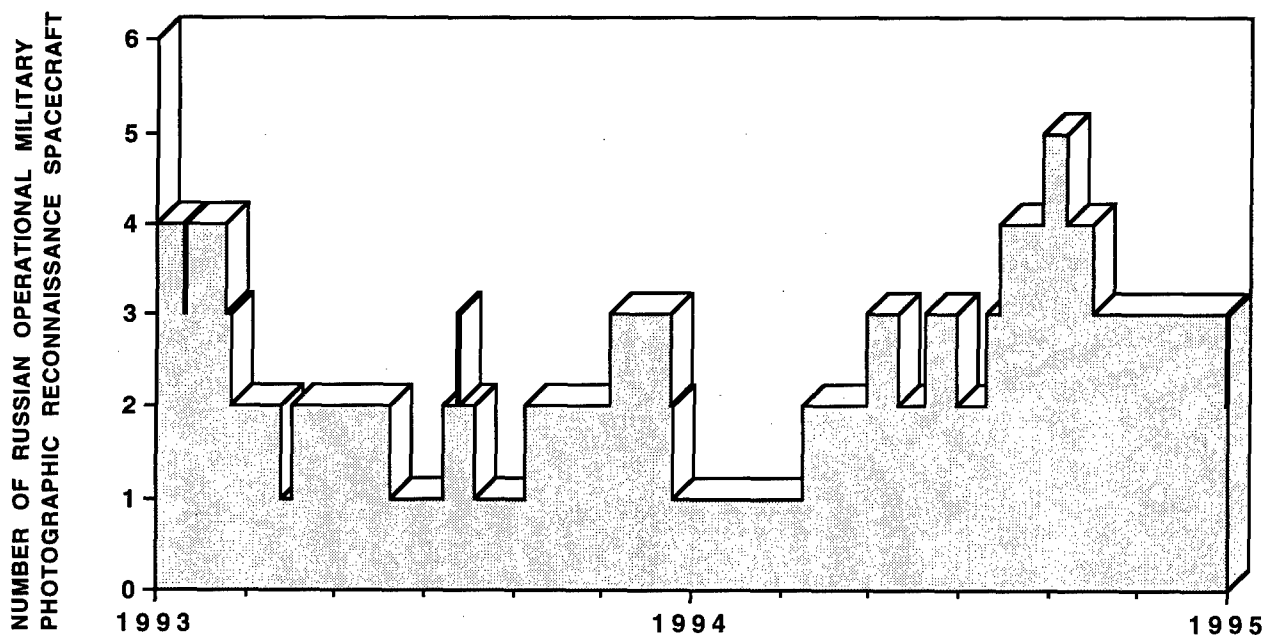


FIGURE 6.2 RUSSIAN MILITARY RECONNAISSANCE ACTIVITY, 1993-1994.



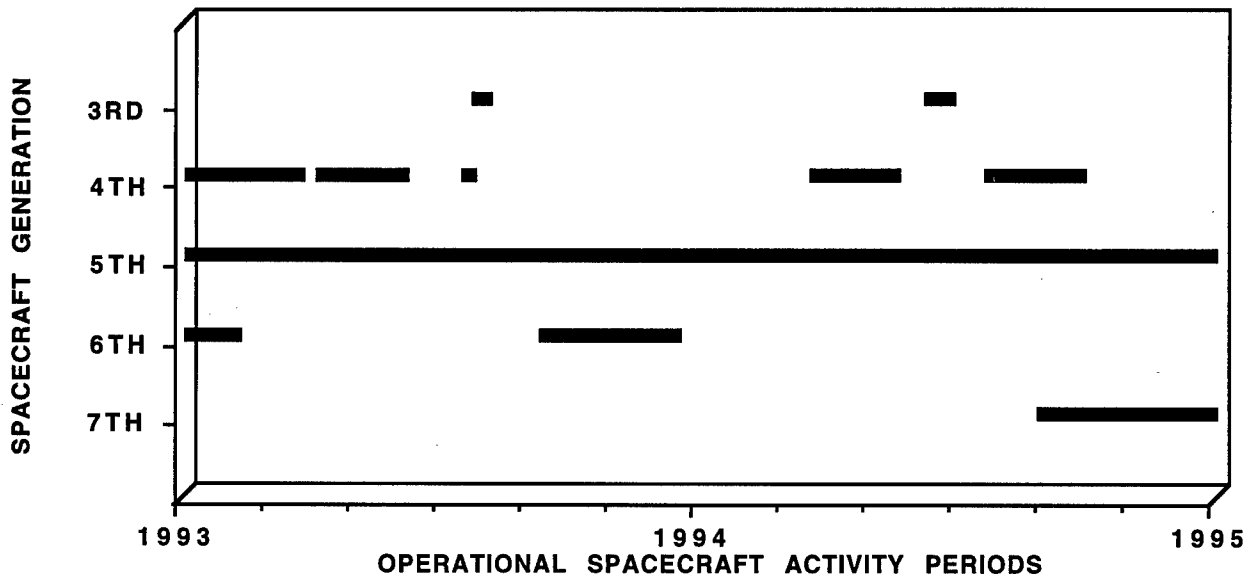


FIGURE 6.3 RUSSIAN MILITARY RECONNAISSANCE PERIODS BY SPACECRAFT TYPE.

argument of perigee will be rotated progressively from ascending passes (first month) to descending passes (second month). Fifth-generation satellites are an exception with arguments of perigee normally maintained between  $80^\circ$  and  $110^\circ$ .

The so-called third-generation photo recons are derived from the original Zenit-2 spy satellites (Figure 6.4) and share many characteristics and systems with the manned Vostok spacecraft of the time and the Resurs-F1 civil Earth observation spacecraft of today. The spacecraft are approximately 2.4 m in diameter with a length of 6.5 m and a mass of about 6.3 metric tons. Film is returned (along with the entire camera system) in a spherical 2.3 m diameter, 2.4 metric ton capsule. Within each capsule is a special detonation package (originally 10 kg TNT) which is activated in the event that a malfunction would prevent a retrieval of the capsule on former Soviet territory (References 37-39).

In recent years, the launch rate of these battery-powered vehicles with lifetimes of 2-3 weeks has dropped dramatically as more capable, longer lived spacecraft have assumed medium-to-low-resolution reconnaissance duties. Only one third-generation Resurs-T spacecraft (possibly also designated Oblique) was launched from Plesetsk in each of 1993 and 1994 and both were described as fulfilling geodetic and cartographic objectives from high

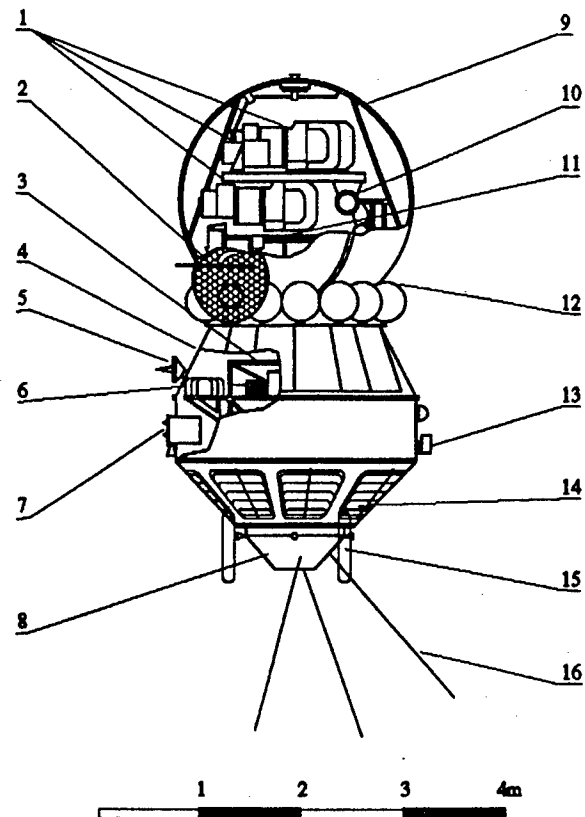


FIGURE 6.4 ZENIT 2 RECONNAISSANCE SPACECRAFT DESIGN.

inclination (83°) orbits: Kosmos 2260 (22 July 1993) and Kosmos 2281 (7 June 1994). Characteristics of their camera systems are unknown.

In 1975 the fourth-generation Yantar photo recon spacecraft debuted for the purpose of taking over the high resolution reconnaissance duties of their predecessors. By flying elliptical orbits with perigees typically near 170 km, fourth generation spacecraft can enhance the resolution of their imaging systems. Principal improvements of the original fourth generation satellites included an extended orbital lifetime (initially 30 days; now 60-70 days) and the capability to return small film capsules during the course of the mission without de-orbiting the entire spacecraft.

The spacecraft is approximately 7 m long and 2.4 m maximum diameter with a mass of 6.7 metric tons. Equipped with two solar arrays, Yantar spacecraft are primarily constrained by maneuvering propellant and film reserves. Kosmos 2283 in 1994 set a new endurance record of 71 days on orbit. During 1993 and 1994 three and two high resolution Yantar spacecraft were launched, respectively, but one, Kosmos 2259 (14 July 1993) failed after about ten days in space. All missions during the period (Kosmos 2231, 2240, 2259, 2274, and 2283) were launched from the Plesetsk Cosmodrome into inclinations of 63°-67°.

A variation of the Yantar-class spacecraft appeared in 1981 (Kosmos 1246) to conduct high-precision topographic surveys. These spacecraft, now referred to as Kometa, typically remain in orbit for 44-45 days and are distinguished by their relatively circular orbits between 210 and 280 km. The Kettering Group also regularly detects geodetic-type signals at 150.3 MHz from this satellite class (Appendix 1). Kometa missions are always launched from the Baikonur Cosmodrome into inclinations of 65° or 70° at the rate of one or two per year.

The only successful mission of this type during 1993-1994 was performed by Kosmos 2284 (29 July 1994). Another Kometa flight was attempted on 27 April under the name of Kosmos 2243. However, the final stage of its Soyuz-U launch vehicle malfunctioned, causing an immediate activation of Kosmos 2243's self-destruction system upon reaching orbit. Kometa spacecraft are believed to carry (1) the TK-350 10-m resolution stereo camera system, produced by the Belarus Optical Camera Com-

pany, with an Earth's surface field-of-view of 180 km by 270 km and (2) the KVR-1000 2-m resolution camera system with an image field-of-view of 40 km by 40 km (see section 4.3.11).

The fifth-generation, digital transmission photo recons debuted in 1982 with the flight of Kosmos 1426. With a reported resolution of at least 2 m, these spacecraft are normally launched once or twice per year from the Baikonur Cosmodrome into inclinations of 64.9° or 70.4°. After the initial mission of 67 days, the fifth generation photo recons quickly extended their normal operational lifetimes to 170-260 days. Beginning in 1992, mission durations increased markedly, culminating in the 418-day flight of Kosmos 2267 (5 November 1993). Data transmissions can apparently be made directly to special ground stations or relayed via geosynchronous satellites of the Geyser class (References 40-45). The fifth-generation spacecraft may resemble the civilian Resurs-Spektr spacecraft (Section 4.3.11).

Kosmos 2267 was the only fifth-generation photo recon launched in 1993, having been launched about six weeks before its predecessor, Kosmos 2223, finished its mission. Kosmos 2267 was joined on 28 April 1994 by Kosmos 2280. For the next eight months, the pair worked together in orbital planes 90° apart, often alternating their orbital maneuvers at roughly 20-day intervals. Kosmos 2267 finally was deorbited over the Pacific Ocean on 28 December 1994, only to be followed the next day by the next in the series, Kosmos 2305 (Reference 45).

A sixth generation of photo recons began operations with Kosmos 2031 in 1989. The spacecraft drew immediate attention with its 50.5° inclination, a rarely used orbit often employed for testing new satellites. (The previous use was the inaugural flight of the fifth-generation photo recon nearly seven years earlier.) The sixth-generation spacecraft, believed to carry both film return capsules and digital transmission capabilities, have only flown five times: once each year during 1989-1993.

Sixth-generation photo recons have only been launched from the Baikonur Cosmodrome using the Soyuz-U2 launch vehicle, which has otherwise been restricted to supporting Soyuz-TM and Progress-M missions. Following the first mission, each spacecraft was inserted into an orbital inclination of 64.8-64.9° with mean operational altitudes normally between 240 and

260 km. Another peculiar, identifying characteristic is the in-orbit detonation of sixth-generation spacecraft at the end of their operational lives. Kosmos 2262, the last sixth-generation mission and the only one to be launched during 1993-1994, nearly doubled the 60-day record of its predecessors with a flight lasting 102 days. The spacecraft was destroyed in orbit as it passed over northeastern Russia, ensuring that much of the debris would fall into the Pacific Ocean.

In August, 1994, an apparently new type of photographic reconnaissance spacecraft was launched as Kosmos 2290. Although its initial orbit of 212 km by 292 km at an inclination of  $64.8^\circ$  was not unusual, its use of a Zenit-2 launch vehicle was. Throughout Kosmos 2290's 221-day mission, the spacecraft behaved similarly to other Russian photo recons, although its apogee altitude was progressively raised during normal anti-drag maneuvers (Figure 6.5). Just prior to its return to Earth, the spacecraft moved into a markedly higher orbit unlike previous military spacecraft. One week later the spacecraft was de-orbited over the Pacific Ocean. In the absence of any information on Kosmos 2290 by the Russian Military Space Forces, the spacecraft's nature is still under investigation in the West, and the spacecraft has tentatively been designated as the first seventh-generation photo recon (Reference 46).

In the 1980's a large synthetic aperture radar reconnaissance system was developed under the then military Almaz program. This system lost support from the Ministry of

Defense and was eventually converted into a quasi-commercial Earth observation program (Section 4.3.11) with flights in 1987 and 1991. No comparable SAR system is now known to be under development by the Russian Federation for dedicated national security applications.

#### 6.1.6 Spain

Although the smallest contributor to the French-Italian-Spanish Helios program (Section 6.1.1), Spain has made a commitment to using space-based assets to bolster national security. In addition to the Helios data reception center at Maspalomas, Canary Islands, Spain hosts the Western European Union Satellite Center in Torrejon which interprets data from civil Earth observation satellites and will receive images for Helios once it becomes operational. Spain has reiterated its intention to participate in the Helios 2 program.

#### 6.1.7 Western European Union

The Western European Union, consisting of nine principal member states (Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Portugal, Spain, and the United Kingdom), and 18 other nations in lesser roles, constitutes the defense organization of the 12-state European Union. Since 1988 the WEU has considered the formation of a space agency, the European Satellite Control Agency (ESCA), with a primary objective of performing national security reconnaissance from space with emphasis on treaty verification capabilities. The WEU held a collo-

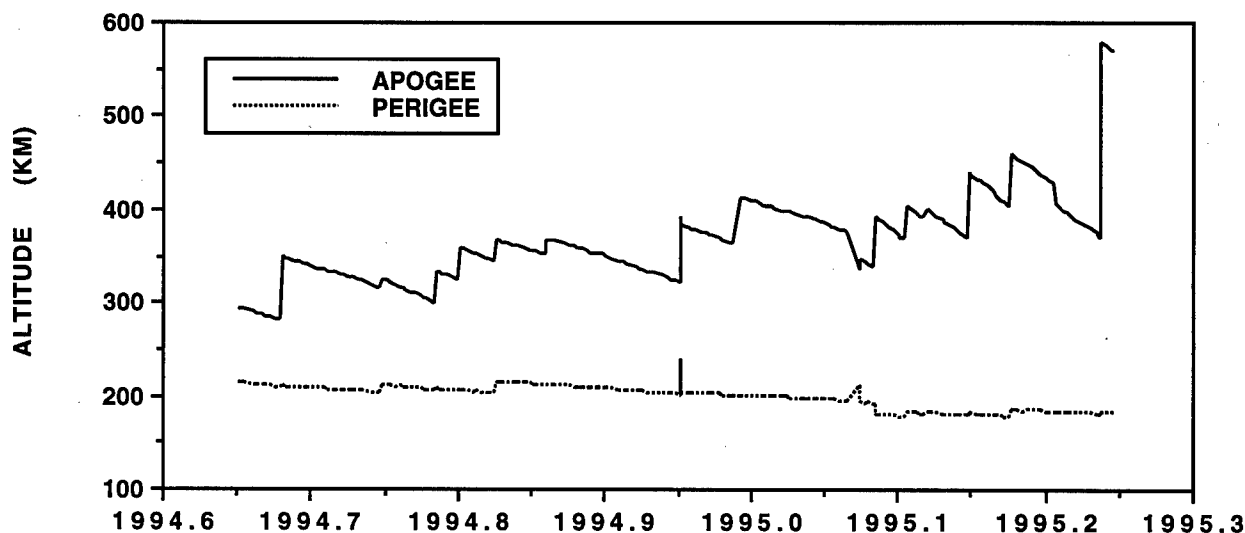


FIGURE 6.5 KOSMOS 2290 ORBITAL HISTORY.

quy in Paris in June, 1993, to further examine the requirements and utility of an ESCA. After postponing a decision of integrating WEU requirements and funding with the French-led Helios program, the WEU in 1991-1992 decided to establish an image processing and interpretation center which would initially work with data from SPOT, Helios, ERS, and other commercial sources, including data from Russian photo recons.

The WEU Satellite Center at Spain's Torrejon Air Base near Madrid opened in April, 1993, and almost immediately came under fire for its limited data processing capabilities. After overcoming additional budget pressures, the center appeared to be on firmer ground by the end of 1994 with a decision expected in 1995 to make the facility permanent. The center's present objectives are to demonstrate the application of space imagery in the fields of treaty verification, crisis-monitoring, and environmental monitoring. The concept of operating an independent WEU satellite system, perhaps by taking over the Helios 2 and Horus programs, has gained some support in the WEU. However, simultaneous operations of Helios and a separate WEU network are unlikely (References 47-57).

## **6.2 ELECTRONIC INTELLIGENCE**

Electronic intelligence (ELINT) satellites, which use active or passive techniques to detect specific targets, complement the data returned by imaging reconnaissance satellites to provide a more complete picture of an adversary's forces or intentions. The most common ELINT satellites are designed to pickup radio and radar emanations of ships at sea, mobile air defense radars, fixed strategic early warning radars, and other vital military components for the purpose of identification, location, and signals analysis.

The data can then be used for weapons targeting, offensive and defensive engagement planning, and even countermeasure development. In a conflict, the electronic order of battle (EOB) provided by space-based ELINT systems may be even more valuable than conventional photographic reconnaissance. Unlike photo recon satellites, ELINT spacecraft can fly at much higher altitudes without significant impact on sensitivity (the ELINT counterpart to photo recon resolution). Consequently, ELINT satellites can exploit very wide fields-of-view and thereby broaden coverage of terrestrial regions

considerably. Since ELINT satellites operate independently of lighting conditions, small constellations of satellites can provide regular, frequent interception opportunities.

### **6.2.1 France**

While no European or Asian country other than the Russian Federation currently operates ELINT satellites, France will deploy its first satellite of this type in 1995 under the CERISE (Characterisation de l'Environnement Radio-electrique par un Instrument Spatial Embarque) program. A much more capable satellite named Zenon is under development for launch sometime about the turn of the century. The CERISE satellite is actually a 50-kg mini-satellite which will be carried piggyback with the Helios 1A military reconnaissance satellite (Section 6.1.1). Based on the UK's UoSAT spacecraft bus, CERISE is being designed and manufactured by Alcatel Espace. The project is viewed as largely experimental, and CERISE will have the capability of detecting a limited portion (high frequency) of the electromagnetic spectrum. A follow-on spacecraft named Clementine is tentatively scheduled for launch in 1998 to exploit low frequency signals.

Anticipating practical results, the French government in 1992 began studying the feasibility of deploying and operating the large, dedicated Zenon ELINT satellite. The space architecture of a potential Zenon network is still in a formative stage. The program may concentrate on studying the emissions of foreign tactical and strategic radars (References 58-62).

### **6.2.2 Russian Federation**

The Russian Federation is the only member of the European space community known to operate ELINT satellite systems. Since 1967 approximately 200 spacecraft have been orbited by the former Soviet Union/Russian Federation for dedicated ELINT missions. Additional spacecraft may have carried ELINT packages as secondary payloads. During 1993-1994 a total of 11 Russian ELINT spacecraft, representing three classes of vehicles, were launched, although one satellite failed to reach orbit due to a booster malfunction. At the beginning of 1995 the integrated Russian ELINT constellation consisted of 11 primary spacecraft.

Two of the three ELINT networks established and maintained by the USSR/CIS are believed to be global in nature, i.e., they are

designed to detect land-based as well as sea-based electronic signals. The principal mode of operations is for each satellite to record the type of signal received and to determine the direction of the transmitter from the satellite's position. These data are then stored and forwarded to special receiving stations or are relayed in near-realtime via data relay satellites. Analysts on the ground can then combine the data from several satellites to pinpoint the location of the receiver and to determine the type of the emitter. For mobile targets, the frequency of ELINT overflights is crucial to maintaining an accurate knowledge of the target's position.

Historically, ELINT systems have played a major role in Soviet military doctrine. With the dramatic increase of radio and radar emitters on the battlefield during the past 30 years, the value of ELINT satellites has also risen. In the former Soviet Union, the Chief Intelligence Directorate of the Soviet General Staff (GRU) was tasked with the primary responsibility for global ELINT satellite systems. Collection activities were managed by the Satellite Intelligence Directorate, while the data analysis function was performed by the Decrypting Service (References 63-65).

At the end of 1994 the Russian global ELINT satellite capability was distributed between a second-generation, store/dump system nearing the end of a long (15 year) service record and a more advanced model which will probably remain the principal intelligence gathering system for the remainder of this decade. The former has apparently been reduced to a constellation of three or less spacecraft, known as Tselina D, placed in orbital planes 30° apart at altitudes of 635-665 km, while the latter is now represented by four spacecraft, known as Tselina 2, in orbital planes 40° apart at altitudes of 850 km.

Tselina D spacecraft, launched exclusively by the Tsyklon-3 launch vehicle since 1983, are estimated to have a mass of less than two metric tons. The similarity of their orbits to Okean satellites, their similar radar cross-sections, and their lack of maneuverability, suggest that these ELINT spacecraft, like their Tselina D cousins, are the product of the Ukrainian Yuzhnoye Scientific Production Association, the makers of Okean. A report in 1985, citing a classified GAO study, estimated that these ELINT satellites could determine the location of pulsed emitters

with an accuracy of about 10 km (Reference 66).

The original Tselina D constellation consisted of six spacecraft in evenly spaced orbital planes, but by the end of 1992, the network appeared to have been reduced to only three satellites with 60° orbital plane separations. The only launch of 1993 occurred on 16 April when Kosmos 2242 was inserted into an orbital plane midway between the previous two missions (Kosmos 2221 and Kosmos 2228), forming a potential new system of three spacecraft in orbital planes only 30° apart.

The only other apparent Tselina D mission of the 1993-1994 period failed on 25 May 1994 when a Tsyklon-3 launch vehicle suffered a staging malfunction and its payload fell back to Earth into the East Siberian Sea. The timing of the launch from the Plesetsk Cosmodrome suggested an attempt to "replace" the old Kosmos 1975 spacecraft, whose orbital plane was 90° away from Kosmos 2242, and the spacecraft may have been the last of its kind. The operational status of the Tselina D constellation can be inferred by Kettering Group interceptions of the spacecraft's CW beacon operating at about 153 MHz (Appendix 1).

A successor to the Tselina D network, Tselina 2, began flight testing in 1984. Launched by Zenit-2 boosters from the Baikonur Cosmodrome, these more modern ELINTs are assessed to be capable of near-realtime downlinks via Geyser geosynchronous spacecraft. (The first two missions were launched by the Proton-K booster before the Zenit-2 was available.) The higher altitude and lower inclination (71.0° versus 82.6°) of Tselina 2 as compared to Tselina D actually increase the frequency of detection in the temperate zones without sacrificing polar coverage. The Yuzhnoye NPO is responsible for both the launch vehicle and the spacecraft (References 67-68).

After nine launches (including one launch failure) during the first six years, the program was wrecked by three successive Zenit-2 launch failures between October, 1990, and February, 1992. The first mishap occurred after only three seconds into the flight and resulted in the complete destruction of the Zenit launch pad. The subsequent two failures were traced to heating problems in the second stage main engine. During this time the then-Soviet period-

cal Red Star acknowledged the mission of the Tselina 2 was to "verify the fulfillment of disarmament treaty commitments" (Reference 69).

Finally, in November and December, 1992, more than two years after the trio of Zenit-2 launch failures began, replenishment Tselina 2 spacecraft were successfully deployed under the guise of Kosmos 2219 and Kosmos 2227. Together with Kosmos 2082 (May, 1990), the new spacecraft formed a network of three orbital planes spaced approximately 45° apart.

Two missions were attempted in each of 1993 and 1994, but the first of these spacecraft (Kosmos 2237, 26 March 1993) failed within a few days of launch. Initially, the malfunction was believed to have been caused by collision with a piece of debris from its Zenit-2 second stage. The stage had exploded shortly after reaching its desired orbit (as had Kosmos 2227's launch vehicle) due to unexpected side-effects of the fix implemented to solve the main-engine failures of 1991 and 1992 (Reference 70). An investigation later concluded that the Kosmos 2237 spacecraft itself was at fault.

The next three spacecraft (Kosmos 2263 in September, 1993; Kosmos 2278 in April, 1994; and Kosmos 2297 in November, 1994) experienced nominal deployments. However, a slight constellation alteration was apparently introduced. At the end of 1994 Kosmos 2227, 2263, 2278, and 2297 formed a regular network of orbital planes spaced 40° apart, rather than the earlier 45° separations.

Since 1974, a separate, highly specialized ELINT Ocean Reconnaissance Satellite (EORSAT) system has been operated by the USSR and then the Russian Federation.

The objectives of the EORSAT system are to detect, identify, and track Western shipping, particularly naval task forces which might threaten the CIS or are engaged in a conflict elsewhere in the world. More importantly, EORSATs are designed to provide direct tactical support to CIS forces in the form of weapons targeting data via the near-realtime transmission of its intelligence information (References 67, 71-73). Such data can be beamed directly to CIS ships equipped with Punch Bowl antennas

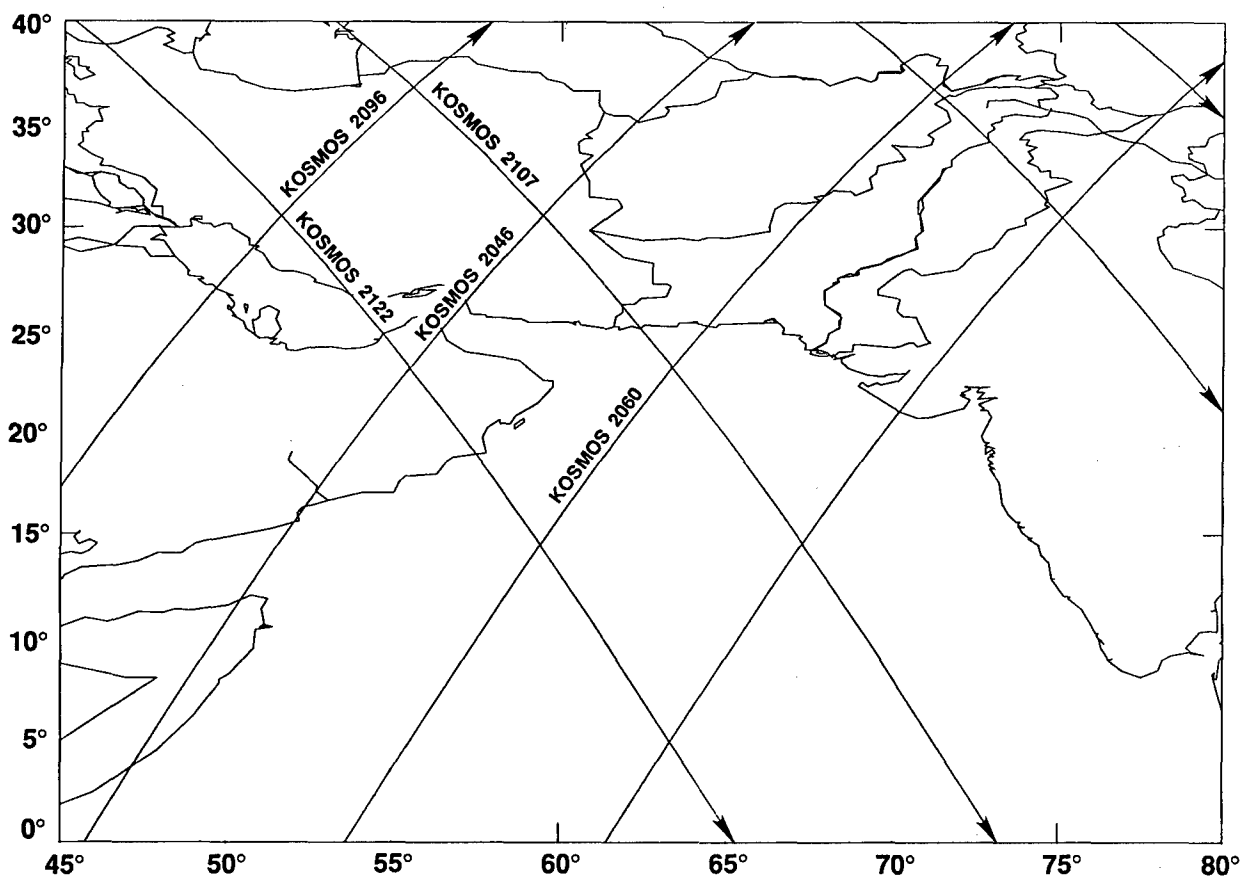


FIGURE 6.6 EORSAT COVERAGE OF THE PERSIAN GULF WAR REGION.

or sent to Moscow for relay via Molniya and Raduga satellites to Russian or CIS vessels carrying Big Ball communications antennas (References 74-76).

Since naval vessels may be in transit at high speeds, several sightings in a short period of time are desired to determine location, heading, and speed. To accomplish this the EORSAT constellation normally consists of multiple satellites in two orbital planes. A complete EORSAT constellation might consist of six satellites with three satellites evenly spaced in each of two orbital planes separated by approximately  $145^\circ$ . This arrangement ensures a flurry of over-flights for specific regions, increasing the probability of detection and the accuracy of position and movement data (Figure 6.6). EORSATs are believed to be capable of estimating naval positions to within two kilometers (Reference 66).

The current operational orbit for EORSATs is 404 km by 417 km at an inclination of  $65^\circ$ . This altitude regime is rigidly maintained ( $\pm 1$  km) with frequent orbital maneuvers as are the relative spacings of EORSATs to adhere to a strict groundtrack pattern which repeats every three days (46 revolutions). All operational EORSATs possess the same set of 46 ascending nodes and are primarily phased in time. A geometric analysis suggests that this phasing is linked to the field-of-view of the satellites for their selected altitude (Reference 77).

Like the global ELINTs, EORSATs are subservient to the GRU, although they are operated by the Department for Satellite Intelligence of the Naval Intelligence Directorate of the Main Navy Staff, Naval Headquarters. The organization responsible for EORSATs is the Kometa Central Scientific Production Association, headed by General Director and General Designer Academician Anatoli I. Savin. Major construction activity is performed at the Arsenal enterprise in St. Petersburg. The Kometa TsNPO is also known to be responsible for the sister Radar Ocean Reconnaissance Satellite (RORSAT), which operated during 1970-1988, as well as other high value tactical and strategic space systems.

The EORSAT is a 3,000 kg spacecraft principally comprised of a 1.3 m diameter, 17.0 m long cylindrical bus and two large solar arrays (Figure 6.7). From documents and information released by the Arsenal Design Bureau under its Konversia (conversion) program, the EOR-

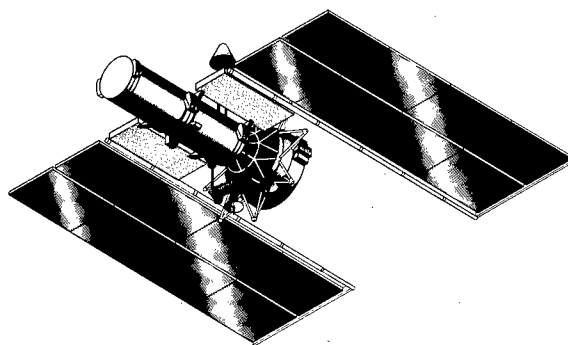


FIGURE 6.7 EORSAT SPACECRAFT BUS.

SAT bus contains a primary injection engine (the Tsyklon-2 launch vehicle inserts the EORSAT into a 120 km by 415 km transfer orbit from which the spacecraft maneuvers into its circular operational orbit) of 300-600 kg thrust. Four 10-kg-thrust attitude control engines are also carried. All propulsion systems employ UDMH and  $N_2O_4$  stored in eight 60-liter tanks. A special communications antenna on top of the vehicle is designed for realtime or near-realtime operations via a geosynchronous relay satellite (presumably Geyser for the EORSAT network). The primary EORSAT payload antenna is apparently configured in the form of an "X" (like the civilian Okean spacecraft) and is carried on the Earth-facing side of the bus (References 78 and 79).

By the beginning of 1993, 37 EORSAT spacecraft had been launched with a maximum, reference orbit lifetime of more than 700 days. EORSATs were characterized by numerous fragmentation events (apparent explosions) during the 1975-1987 period, but current practices dictate a series of perigee-lowering, propellant-depletion burns at the end-of-life. Since this procedure was implemented, all EORSAT fragmentations (involving 16 spacecraft) have ceased.

From a temporary high of six operational EORSATs in late 1990, the EORSAT constellation steadily declined during 1991-1992 (which witnessed only one replenishment launch in January 1991) to a single spacecraft by the beginning of 1993. On 4 March 1993 the last EORSAT spacecraft performed an end-of-life maneuver, terminating all EORSAT activities for the first time since 1983 after setting a record mission duration of 775 days.

This apparent abandonment of the program was short-lived when Kosmos 2238 was launched on 30 March 1993. A month later Kosmos 2244 joined its predecessor and was in turn followed by Kosmos 2258 in early July. All three spacecraft were coplanar and were evenly spaced about their plane at 120° intervals to ensure a common set of precise groundtracks. The final mission of 1993, Kosmos 2264, occurred in September and inaugurated a new orbital plane 145° to the west of the established plane.

The EORSAT network remained unchanged for a full year until Kosmos 2238 was retired on 21 September 1994. A little more than six weeks later, Kosmos 2293 was launched into the same plane as Kosmos 2264, creating a new constellation of two spacecraft in each of two orbital planes (Figure 6.8). No further changes to the constellation were undertaken through the end of 1994.

The Soviet RORSAT program, mentioned briefly above, began sporadic operations in October 1970, after two 1-day flight tests of spacecraft support systems in 1967 and 1968

(Kosmos 198 and Kosmos 209, respectively). Equipped with a nuclear-powered radar, the RORSAT spacecraft could reportedly detect destroyer-size ships in good weather and aircraft carrier-size vessels in rough seas, but submarine detection remained an elusive goal. The RORSAT program ceased flight operations in 1988 after five serious mishaps in 33 missions, including two nuclear reactors falling back to Earth from orbit and two launch failures.

The RORSAT spacecraft possessed some similarities with its EORSAT relation and was 3,800 kg in mass, 1.3 m in diameter, and 10 m in length. The nuclear reactor and high altitude storage system (needed to maneuver the reactor from its operational orbit of 250 km to a long-lived disposal orbit of 900-1,000 km) accounted for 1,250 kg and slightly more than half (5.8 m) the length of the spacecraft. The fuel assembly (53 kg, 0.6 m long, 0.2 m in diameter) consisted of 37 cylindrical fuel elements with 31.1 kg (beginning of life) of 90% U235 enrichment (Reference 80).

Following the reentry of Kosmos 954 over Canada in 1978, the RORSAT reactor under-

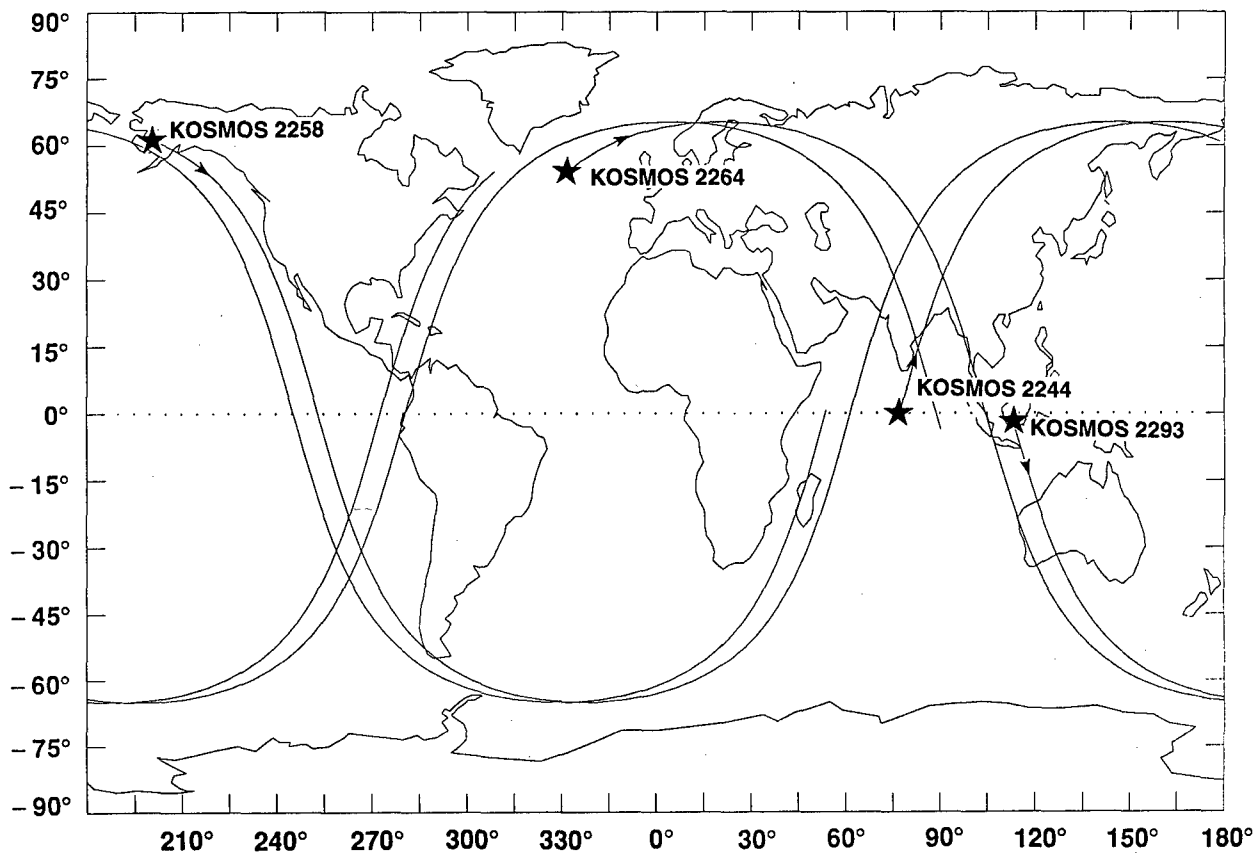


FIGURE 6.8 EORSAT CONSTELLATION CONFIGURATION, NOVEMBER 1994.



went several modifications, including the ability to eject the fuel assembly at the end of life, hopefully in the disposal orbit but prior to reentry in the event of accident, e.g. Kosmos 1402 in 1983. Between 1980 and 1988, at least 14 RORSATs did perform fuel assembly ejection in the higher altitude storage orbits. However, not until 1994 did terrestrial-based space surveillance sensors detect what may be large numbers of very small particles of NaK reactor coolant released when the fuel assembly was ejected (References 80-81).

### **6.3 BALLISTIC MISSILE LAUNCH DETECTION**

In the early 1960's the US and the USSR began deploying large ground-based radars to detect the approach of nuclear warheads launched by ICBMs and later by SLBMs. However, these radars were normally restricted to observing the threat objects relatively late in their trajectories, allowing little time to respond. A space-based surveillance system, on the other hand, would have the advantage of detecting an ICBM or SLBM much earlier, in the powered flight regime. Equally important, launch detection satellites could observe the missiles as a consequence of their infrared emissions, permitting a dual phenomenology (radar and IR) warning system necessary to eliminate false alarms. IR signatures could also be used to identify the type of ballistic missile, indicating the probably nature of the nuclear threat.

For more than 20 years, only the US and the USSR/Russian Federation have operated space-based ballistic missile launch detection systems. Now, due to the proliferation of ballistic missile technology in the Third World and due to advances in IR detectors, other nations, e.g., France, Japan, and the WEU, are now studying the feasibility of national or multinational launch detection networks. Meanwhile, the US, the Russian Federation, and others are examining proposals for new space-based early warning systems which could support national or regional missile defense systems.

#### **6.3.1 France**

During 1994 the French national space agency, CNES, and the firm Matra Marconi closely studied the requirements and benefits of an early warning satellite system. The latter's efforts culminated in a preliminary design fea-

turing two 2,500-kg geosynchronous spacecraft which could be launched by the year 2005. The 600-kg payload would employ a cooled, solid-state array of cells sensitive to IR regime emissions within surface regions of 5 km<sup>2</sup> extent. Position accuracies of up to 100 m at altitudes above 6 km should be achievable. The proposed spacecraft would be 3-axis-stabilized with a maximum electrical power capacity of 2 kW, of which 0.4 kW would be required by the payload. Serious consideration of the proposals was expected in 1995 (References 83-84).

#### **6.3.2 Japan**

With the spread of more capable ballistic missiles in Asia, Japan has recently undertaken increasingly serious studies of early warning and ballistic missile national defense systems. Like its reevaluation of photographic reconnaissance spacecraft, early warning satellites would not violate Japan's prohibition on offensive military space systems. Alternatively, Japan may join with the US in a tactical ballistic missile defense system which would rely on American detection spacecraft in LEO and /or GEO (Reference 85).

#### **6.3.3 Russian Federation**

The Soviet early warning satellite program did not officially begin until the early 1970's under the leadership of Academician Anatoli Savin (now the General Designer and General Director of the Kometa Central Scientific Production Association). The Scientific Supervisor of the project was M. M. Miroshnikov of the Vavilov State Optics Institute, which led to the program sometimes being referred to as Project M (for Miroshnikov). Without extensive Earth observational data in the portions of the electromagnetic spectrum of interest, Soviet designers selected for evaluation three basic types of sensors which might be capable of detecting and tracking a ballistic missile during powered flight. Vidicon tubes sensitive to the near infrared and the ultraviolet were tested for the first-generation system, and infrared solid-state detectors with a mechanical scanner were viewed as a logical improvement for a second-generation spacecraft (Reference 86).

An inability to detect missile engine plumes against the natural background of the Earth led to a decision which directly affected the design of the satellite and the orbital characteristics of the subsequent constellation. Sensors would be

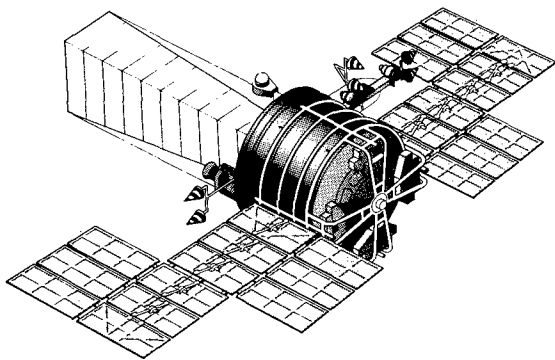


FIGURE 6.9 OKO MISSILE DETECTION SPACECRAFT.

positioned to concentrate surveillance on a region just above the Earth's limb in the vicinity of anticipated ballistic missile launches, i.e., American and Chinese ICBM silos. This requirement in turn made highly elliptical, inclined orbits (of the Molniya class) more attractive than geostationary orbits, which the USSR had yet to exploit.

Although the first in-orbit tests of the Oko early warning spacecraft bus started with the launch of Kosmos 520 in 1972, the first missile detection sensors were reportedly not flown until 1976. The early Vidicon telescopes employed sensor diameters of 0.3-0.5 m with  $4^\circ$  fields-of-view for both IR (0.9-2.2  $\mu$ m) wavelengths. Whereas the IR sensors successfully detected missiles in flight by late 1976, the UV sensors failed repeatedly during the 1976-1978 period and were then abandoned (Reference 86).

The pre-operational early warning spacecraft network began in 1976 with Kosmos 862. The Lavochkin NPO-manufactured satellite was initially 1,250 kg with a diameter of 2.0 m and a length of only 1.7 m, excluding the solar arrays and the sensor sun shield (Figure 6.9). Four years later the transition to a full operational capability with nine satellites in evenly spaced orbital planes was initiated. The constellation comprised the first echelon of the Missile Attack Warning System (SPRN), which was operated by the Air Defense Forces of the Ministry of Defense. According to Soviet officials the early warning satellites could detect missile launches within 20 seconds of lift-off (References 86-91).

Each satellite possessed a perigee of about 600 km, an apogee of nearly 40,000 km, and an

inclination of  $63^\circ$ . This orbit was superficially similar to that employed by Molniya communications satellites but was distinguished by its initial argument of perigee  $316$ - $319^\circ$ , in contrast to the Molniya  $280$ - $288^\circ$  arguments of perigee. The seemingly minor difference significantly affected the shape of the satellite's groundtrack in the Northern Hemisphere.

Russian early warning spacecraft are more affected by gravitational perturbations due to their higher argument of perigee and, therefore, perform periodic station-keeping maneuvers to maintain an acceptable groundtrack. In addition, the argument of perigee migrates slightly over time (due to inclination variations), causing an alteration in the shape of the groundtrack. Instead of expending additional propellant to prevent the argument of perigee shift, Russian spacecraft controllers alter the satellite's ascending node (Figure 6.10). This has the effect of "stabilizing" the apogee point about which surveillance operations are performed.

During 1993-1994 four of the nine operational spacecraft were replaced: Kosmos 2232, Kosmos 2241, and Kosmos 2261 were launched in 1993, followed by the solitary launch of Kosmos 2286 in 1994. At the end of 1994 the early warning constellation appeared to be fully functional with its oldest member (Kosmos 2063) less than five years old. An experimental Oko satellite, Kosmos 2105, completed its mission in 1993. All Oko satellites placed in Molniya-type orbits are launched by the Molniya-M booster from the Plesetsk Cosmodrome.

An early warning satellite network located in GEO could significantly reduce the number of spacecraft necessary for 24-hour surveillance. (Molniya-orbit spacecraft are typically only used for 2 hr 40 min. during each 12 hour orbit.) The first USSR prototype GEO early warning spacecraft was actually tested in 1975, but the first operational spacecraft did not appear until 1984 in the form of Kosmos 1546. Today, 3-4 spacecraft are normally operational at 2-3 positions in the ITU-listed Prognoz series. The preferred locations are  $12^\circ$  E,  $80^\circ$  E, and  $336^\circ$  E with expansion sites at  $35^\circ$  E,  $130^\circ$  E,  $166^\circ$  E, and  $201^\circ$  E.

The first three GEO early warning missions (Kosmos 1546, 1629, and 1894) apparently employed standard Oko spacecraft. The next spacecraft, Kosmos 1940, was experimental in nature with possible nuclear detonation detec-

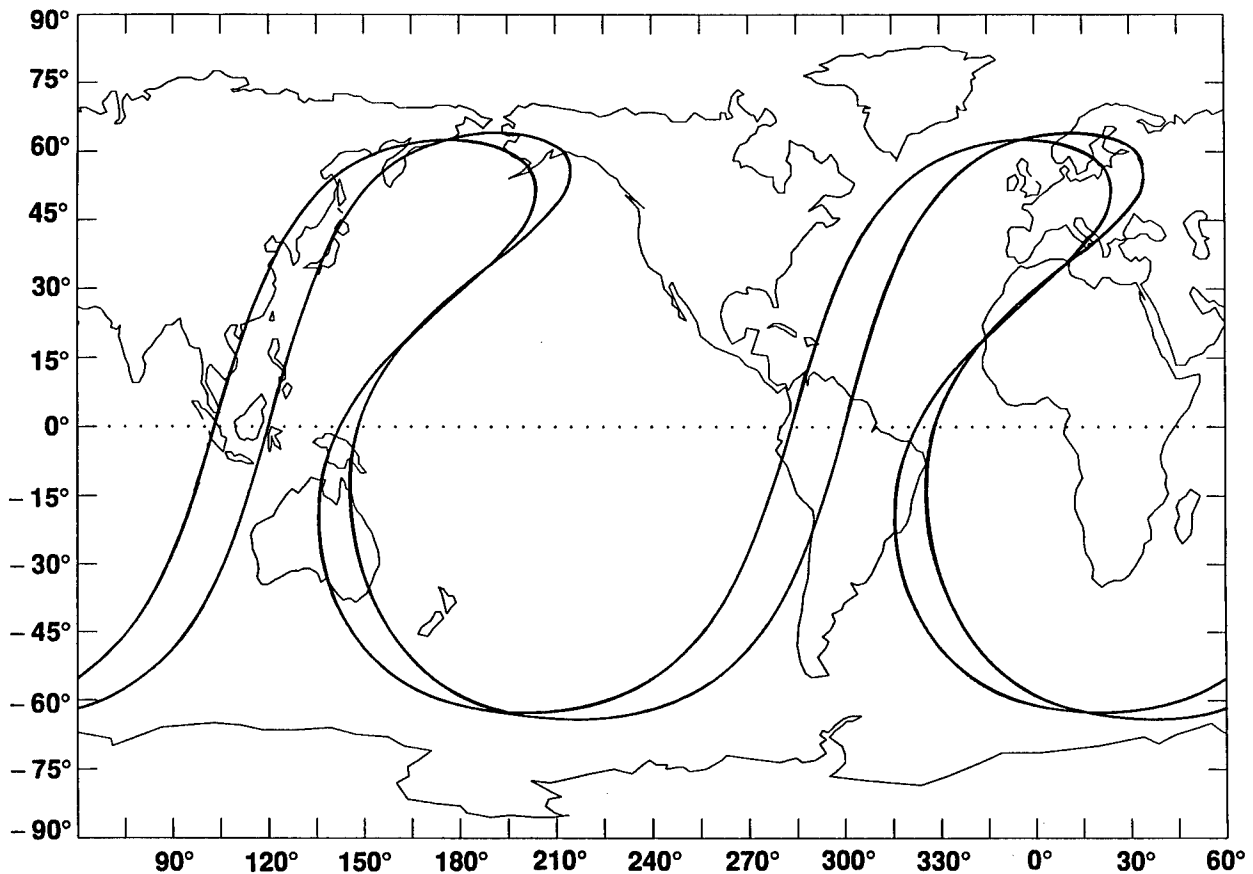


FIGURE 6.10 OKO SATELLITE GROUNDTRACK EXTREMES.

tion sensors. The second-generation early warning satellites debuted under the Prognoz name with Kosmos 2133 in 1990. Based on a new bus similar to Lavochkin's Spektr design (Figure 6.11), the satellite apparently carries a 1 m diameter sensor with a 12,000 element, dis-

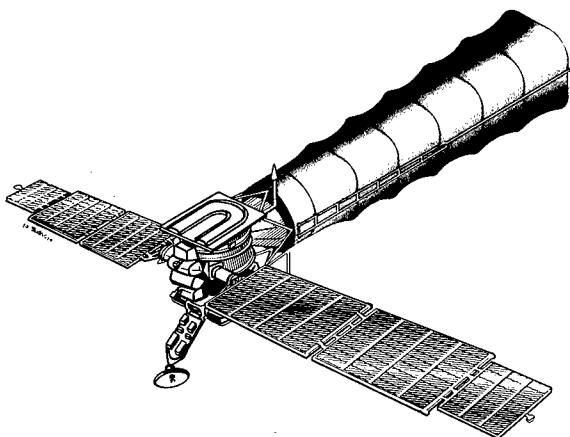


FIGURE 6.11 PROGNOZ MISSILE DETECTION SPACECRAFT.

crete linear detector IR array of PbS material (References 86, 92-93).

At the beginning of 1993, three Russian GEO early warning spacecraft were apparently operational: Kosmos 2133, 2209, and 2224. Kosmos 2133 and 2209 were both positioned at 336° E, but during June-September 1993 the former was transferred to 80° E. At the same time Kosmos 2224, which had been stationed at 12° E was shifted to 336° E beside Kosmos 2209. Then, in late March - early April 1994, Kosmos 2224 was returned to 12° E before Kosmos 2282 was launched in July for operations at 336° E. All GEO early warning satellites are launched by the Proton-K booster from the Baikonur Cosmodrome.

For several years the US and the Russian Federation have discussed the feasibility of exchanging satellite-based early warning data or establishing a joint center in the context of an international early warning or missile defense system. In late 1994 a Russian delegation to the US proposed a new, medium altitude constellation comprised of 18 spacecraft. Meanwhile, two joint US-Russian test programs RAMOS

and Skipper were underway, although neither had been launched by the end of 1994. The RAMOS (Russian-American Observation Satellite) project envisions the launch of two low altitude (425 km) spacecraft equipped with special IR sensors designed to provide simultaneous stereo tracking of theater missiles and environmental phenomena (References 94-100).

The Skipper program was much farther along and completed a Critical Design Review in the Spring of 1994 but missed a planned December, 1994, launch date. The 230-kg spacecraft was to be built by the Moscow Aviation Institute and launched by a Molniya-M booster as a piggyback payload with the Indian IRS-1C remote sensing spacecraft. The principal sensors, UV and VUV spectrometers and photometers, were the responsibility of the Utah State University. From an initial circular orbit of about 820 km, Skipper will lower its perigee in stages to 120-150 km. Data will be collected during atmospheric interfaces near perigee and finally during a planned de-orbit over the Pacific Ocean (References 101-104).

#### **6.3.4 Western European Union**

Closely linked with its foray into space-based military reconnaissance, the WEU is evaluating concepts for early warning satellites in conjunction with a potential European anti-missile defense program. In Rome in 1993, the Technological and Aerospace committee cited the need for "space monitoring and early warning system from which it would be possible to choose an antimissile defense system for Europe" (Reference 105). No specific designs for an early warning satellite system have been released, and a decision to initiate such a major program is not expected in the near-term. French plans for an early warning network (Section 6.3.1) could be adopted, in part or whole, by the WEU.

### **6.4 SPACE DEFENSE**

Space defense is an integral part of the broader concept of space control, which asserts one's ability to act freely in space while denying the same privilege to one's enemy. Space control is analogous to air superiority and sea control in the terrestrial environment. Space defense encompasses the active use of force in space to disable or destroy the satellites or weapons systems of an adversary. The first case, more commonly referred to as anti-satellite (ASAT) operations, may be executed by

another satellite, by a ballistic missile, or from a terrestrial-based directed energy weapon (DEW) facility. A defensive satellite (DSAT) may be positioned near high-value national space assets to protect them against attack by enemy forces. Space-based weapon platforms may also be used to counter surface-to-surface ballistic missiles or even to attack terrestrial targets. To date, only ASAT systems have been formally deployed.

#### **6.4.1 Russian Federation**

In 1963-1964 the Soviet Troops of Air Defense (PVO) established two new commands: PRO and PKO. PRO, meaning anti-missile defense, was charged with detecting, intercepting, and destroying enemy ballistic rockets, while the PKO, meaning anti-space defense, was responsible for "destroying the enemy's cosmic means of fighting" (Reference 106). In 1992 the USSR Space Units which include PRO and PKO were essentially transferred to the CIS United Armed Forces. However, on 7 May 1992 the armed forces of the Russian Federation were established with specific air and space defense missions.

To implement a space control regime and to fulfill its space defense obligation, the PKO began developing ASAT capabilities. Today, the Russian Federation is commonly believed to have acquired four basic ASAT systems with varying degrees of effectiveness. However, the operational status of these systems is a topic of considerable debate.

The principal and only dedicated ASAT system is referred to as the Co-orbital ASAT in reference to its engagement profile. Developed by the Kometa TsNPO under Academician Savin, the Co-orbital ASAT is based on the Tsyklon-2 booster and was tested 20 times in space during the period October, 1968-June, 1982. For each test a dedicated target vehicle was first placed into a low Earth orbit (the first two by the Tsyklon-2 from Baikonur and later targets by the Kosmos-3M from Plesetsk). The Co-orbital ASAT would then be launched from Baikonur on either a 1-revolution or a 2-revolution intercept. The interceptor (Figure 6.12) was 1,400 kg with a principal diameter of 1.8 m and a length of 4.2 m, while the target was a 650-kg polyhedron with a diameter of 1.4 m.

The co-orbital plane requirement meant that launch opportunities occurred as the orbital

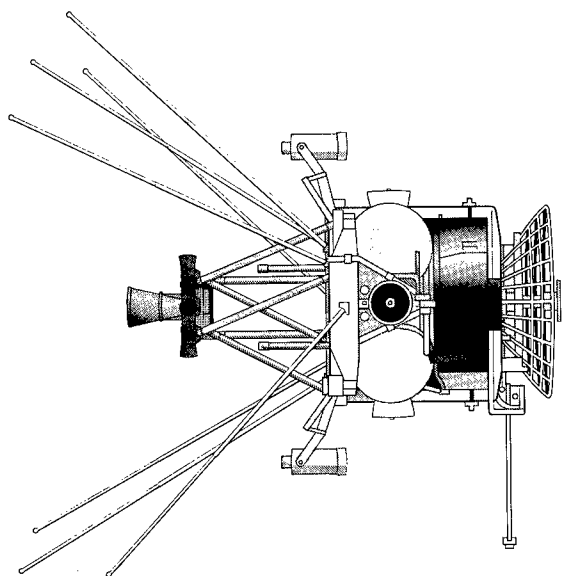


FIGURE 6.12 CO-ORBITAL ANTI-SATELLITE VEHICLE.

plane of the target satellite passed through the Tyuratam launch site twice each day. In practice, only one opportunity per day was acceptable to prevent launches toward the PRC. From an initial, low-altitude parking orbit, the Co-orbital ASAT would quickly maneuver into a transfer orbit with a greater or lesser orbital period than the target to permit an intercept over Europe after one or two complete circuits about the Earth, i.e., approximately 90-200 minutes after launch. Within minutes of the actual attack, the Co-orbital ASAT would maneuver a final time to establish the required end-game conditions. A conventional warhead would then be detonated to effect the negation.

The initial test phase of the Co-orbital ASAT program was conducted during 1968-1971 with an assessed five successes out of seven attempts. In all but one case, a cloud of debris caused by the breakup of the Co-orbital ASAT at the time of warhead detonation was left in LEO. This series of tests validated the operational envelope of the weapon from as low as 230 km to a height of 1,000 km.

Between 1976 and 1982 13 more tests were conducted, primarily to perfect a more rapid intercept profile and to evaluate a new acquisition sensor. Whereas the first seven tests had all required two revolutions, tests 8 and 9 attempted single-revolution attacks as did

tests 12 and 13. In both cases the first attempt was judged a failure and the second attempt a success. The last of these tests demonstrated a reach to an altitude of nearly 1,600 km.

Several of the other missions in the Phase 2 test program reportedly employed an optical or IR sensor for target acquisition rather than the standard radar seeker. All attempts with the new sensor are believed to have failed. However, a radar-equipped Co-orbital ASAT was flown on a 2-revolution profile in 1977 to prove that a target at an altitude as low as 159 km in an elliptical orbit could be successfully negated.

All missions after 1970 were flown at inclinations near  $65.8^\circ$  to satisfy range safety restrictions at both Plesetsk (target) and Baikonur (Co-orbital ASAT). The lack of testing for more than 12 years has raised some questions about the current operational status of the Co-orbital ASAT. The Tsyklon-2 has been flown frequently in support of ocean reconnaissance programs and in August, 1989, the US Secretary of Defense claimed "conclusive evidence" existed that the system was "in a constant state of readiness." Nearly three years later a Russian publication appeared to confirm its operational status (Reference 107). Two launch pads are available at Baikonur, each capable of supporting several ASAT missions per day (Reference 108). Although the Co-orbital ASAT has never been launched from Plesetsk, the assumed commonality of Tsyklon-2 and Tsyklon-3 launch pads should make such operations feasible.

A second ASAT capability is actually older than the Co-orbital ASAT but also much more limited in range. Since the 1960's the USSR/Russian Federation has operated a limited ABM system around Moscow. Originally employing the Galosh nuclear-tipped interceptor developed by G. V. Kisunko's Design Bureau No. 1, the system now possesses the Gazelle and the Gorgon missiles for endo- and exo-atmospheric engagements, respectively (Reference 109). The silo-launched Gorgon is probably capable of intercepting very low altitude (only a few hundred kilometers) satellites which pass above the Moscow region. This substantially limits the number of satellites potentially vulnerable to the Gorgon, which would be guided to its target by the new Pill Box phased-array radar at Pushkino. Moreover, the use of a nuclear warhead at a low altitude above Moscow would result in collateral damage due to the effects of electromag-

netic pulse (EMP). Additional Gorgon interceptors may be operational at the Sary Shagan ABM test range in Kazakhstan (References 110-111).

Whereas the Co-orbital ASAT and the Gorgon ABM interceptor are limited in their ability to negate only satellites in LEO, electronic warfare techniques, known as Radio Electronic Combat (REC) in the Russian Federation, are potentially effective at all altitudes, including GEO. In the late 1980's, Russian officials openly acknowledged not only the possibility of employing REC against enemy satellites but also the country's interest and ability in such methods (References 112-113). REC is a basic tenet of Russian terrestrial war-fighting doctrine, but its application to satellites may leave the attacker with considerable uncertainty as to the outcome of the engagement.

From the 1970's, the USSR was involved in an extensive, multi-faceted program to develop high-powered, ground-based lasers and microwave weapons. The centers of this activity, with potential ASAT applications, were at Sary Shagan and at Troitsk near Moscow. At least two major facilities were constructed at Sary Shagan: one a 0.7  $\mu\text{m}$  ruby laser and one a 10.6  $\mu\text{m}$  pulsed CO<sub>2</sub> laser. Both lasers shared a common one-meter diameter beam director. Although Soviet officials admitted the facilities had been used to track satellites prior to 1988, no lethal capability was said to exist (References 112-116). A 1 MW gas laser was built at Troitsk outside Moscow in the late 1970's for military purposes, but a purported ASAT role was not realized (References 117-120). One of the principal developers of both ground-based and space-based laser designs was the Astrophysika Scientific Production Association, which was responsible for the elaborate free-electron laser (FEL) prototype ASAT weapon at Storozhevaya.

The level of damage inflicted by a laser on a satellite may range from hard kill (including fragmentation) to general component damage to special component damage. Hard kill normally requires very high energy deposition which is currently possible only at relatively low altitudes of a few hundred kilometers. General component damage may extend above 1,000 km, and special component damage (e.g., sensitive payload optics or attitude control sensors) may be possible as high as GEO. However, the magni-

tude of the last two levels of damage may be difficult to determine by the attacker, reducing the operational utility of the technique as an ASAT weapon.

By moving the laser platform into Earth orbit some difficulties can be overcome, in particular atmospheric attenuation of the laser's energy can be eliminated. If the space-based laser (SBL) is maneuverable, the range to the target can be reduced, increasing the energy deposition and possibly enhancing the probability of a hard kill. In addition, the SBL could serve an ABM as well as an ASAT role. On the other hand, SBLs are much more limited in the amount of lasing medium and power available and are essentially unserviceable.

Following the attempted coup in the USSR in 1991, a number of reports began to emerge about an effort to deploy SBLs in conjunction with a strategic defense program. The Polyus 80-metric-ton vehicle carried on the first Energiya mission in 1987 included the Skif-DM payload, which was "intended for perfecting the design and on-board systems of a future military space complex with laser weaponing" (References 121-125). Whereas Polyus was primarily a product of the Salyut Design Bureau and the Khrunichev Machine Building Plant, Skif-DM was designed by the Institute of Thermal Processes, well-known for its work with nuclear energy. Polyus/Skif-DM failed to reach orbit due to an attitude control problem and fell into the Pacific Ocean after separating from the Energiya booster. No further launches have been attempted.

A more conventional ASAT program was also underway in the late 1980's and early 1990's. A specially configured MiG-31 was designed to carry an air-launched missile equipped with a satellite-homing, kinetic-kill warhead (Reference 126). Very similar to the US F-15 air-launched ASAT, successfully tested against a satellite in September, 1985, the USSR/CIS miniature ASAT would have been restricted to satellites in LEO, but it would have considerably greater flexibility for engaging enemy satellites than the Co-orbital ASAT. Perhaps more important would be its ability to attack with virtually no warning, unlike the Co-orbital ASAT. The status of the Russian air-launched ASAT today is unclear, but Russian officials in 1992 indicated that future space tests were possible.

## 6.5 NATIONAL SECURITY SUPPORT SYSTEMS

To perform the early warning, space defense, and general space surveillance functions, a nation must regularly calibrate its large ground-based radars and update its upper atmospheric (<2,000 km altitude) models. In part, these activities are carried out with the aid of a variety of relatively small satellites, often referred to as minor military spacecraft. As the only European-Asian country engaged in the above functions, the Russian Federation is also the only member to undertake an extensive program of this nature.

### 6.5.1 Russian Federation

For more than 30 years (1962-1994) the USSR/CIS orbited on average five spacecraft per year believed to be associated with the support of national security systems. However, since 1991 these activities have markedly decreased with only one such mission in each of 1993 and 1994. Moreover, unique orbital operations associated with some of these spacecraft have essentially ceased.

Through the years a wide variety of passive and active spacecraft have been launched in this program by Kosmos-2, Kosmos-3M, Tsyklon-3, and Zenit-2 launch vehicles. In general, satellites are inserted into low, nearly circular orbits (350-550 km) or into moderately eccentric orbits between 200 km and 2,600 km. The primary inclinations used have been 50.7°, 65.8°, 74° and 82.9°. The first inclination has not been used since 1987 when the last space mission was flown from the Kapustin Yar Cosmodrome.

Specific techniques and orbital profiles have evolved, but minor military satellites have fallen into two basic categories: those which release multiple objects during their missions and those which do not. The former class of satellites have been linked to the calibration and testing of USSR/CIS radars, in particular ABM radars, while the latter group probably perform a variety of functions, including atmospheric density investigations (Reference 127).

The two missions launched in 1993-1994 for the Russian Military Space Forces were simple, 2-m-diameter spheres inserted into moderately elliptical orbits by Kosmos-3M boosters from Plesetsk. Kosmos 2265, launched in October, 1993, into an orbit of 291 km by 1573 km, was reportedly a Yug spacecraft with no exterior coverings or appendages, ideal for uniform

optical and radar reflections. Kosmos 2292, launched in September, 1994, into an orbit of 400 km by 1,954 km, appears to have been a Vektor-class spacecraft. Although similar in size and shape to the Yug, Vektor satellites are covered with solar cells and carry four deployable antennas. Seven spacecraft launched since 1974 (beginning with Kosmos 660) belong to the Kosmos 2292 class, and all are still in orbit (Reference 128).

A total of 20 spacecraft with sub-satellite release capabilities, designated Romb, were orbited during 1980-1990 with demonstrated capacities of 8-37 sub-satellites. These spacecraft normally begin life in nearly circular orbits of approximately 500 km altitude. The ejection events may occur at anytime and may involve only a few or many objects, although almost always in even numbers. For example, Kosmos 2053 was launched on 27 December 1989 and by the end of 1992 had released a total of 37 objects during nine operations spanning 18 months. The smallest number released at one time was two and the largest number was eight. In contrast, Kosmos 1494 waited five months before ejecting its full complement of 25 sub-satellites in a week's time. Many of the sub-satellites appear to be ejected in opposite pairs from the parent satellite.

In many cases the release of a batch of new sub-satellites with diameter of 30 cm is closely tied to the decay of an earlier set (Reference 129). While a link between the sub-satellites and testing ABM radars dates back to at least 1981 (Reference 130), an analysis by G. E. Perry of the Kettering Group strongly suggests that this is still a principal objective. His work showed a close correlation between ejection events and immediate passes over the Moscow area (Reference 131). During 1993-1994 only one ejection event involving a single sub-satellite from Kosmos 2106 (launched in 1990) was detected, occurring in early February 1993.

### 6.6 UNKNOWN MISSION

By their classified nature, national security programs are often difficult to assess by simple official pronouncements or orbital analyses. Often, when a new military space program is introduced, several flights are required before a public determination of its probable objective can be made. This situation is particularly applicable to non-maneuvering LEO spacecraft at moderate altitudes between 500 and 2,000 km.

#### **6.6.1 Russian Federation**

As noted in Section 6.1.5, the Russian Military Forces introduced an apparently new photographic reconnaissance system or variant in 1994 with the flight of Kosmos 2290. Whereas its nature was readily discernible by its orbital behavior, the mission of Kosmos 2285, which was launched three weeks earlier, remained undefined at the end of the year. Kosmos 2285 was launched by a Kosmos-3M booster from the Plesetsk Cosmodrome and inserted into an orbit of 974 km by 1013 km at an inclination of 74.0°. This orbital regime had not been employed by the USSR/CIS since 1972 when an early generation navigation satellite system was shifted to the present-day 83° inclination (Section 4.2.6).

According to an ITAR-TASS news release, "the launch had been successful and that it was carried out in the interests of the Ministry of

Defense" (Reference 132). Through early 1995 the spacecraft exhibited no maneuverable characteristics, and its radar cross-section of a few square meters was consistent with Parus and Tsikada class gravity-gradient satellites. Also like most LEO navigation satellites, no operational debris was found after deployment which might suggest the release of special sensor covers or appendages such as solar arrays or antennas.

In addition, no signal receptions from Kosmos 2285 were reported by the Kettering Group, thereby preventing a possible association with other military space systems. Visual observations of Kosmos 2285 by Paul Maley indicated that the spacecraft presented an optical signature virtually identical to Russian LEO navigation satellites. Further information or flight activity will be required before Kosmos 2285 can be better categorized.



## References - Section 6

1. C. Covault, "Soviets Endorse French Proposal for Space Reconnaissance Agency", Aviation Week and Space Technology, 24 October 1988, p. 23.
2. "France Studies Reconnaissance Version of Spot Spacecraft", Aviation Week and Space Technology, 10 August 1981, p. 58.
3. "France To Build 'Third Great' Force in Space", Military Space, 14 April 1986, pp. 4-5.
4. "France Approves Military Recon and Communications Satellites", Defense Daily, 5 February 1987, p. 196.
5. T. Furniss, "European Spies", Flight International, 18-24 January 1995, pp. 43-44.
6. S. Chenard, "French Satellites in Uniform", Space, September-October 1994, pp. 8-12.
7. P.B. de Selding, "Space Firms Turn to Military Work as Anchor", Space News, 1-7 November 1993.
8. "French Milspace", Military Space, 27 April 1987, p. 8.
9. "France Approves Launch by Ariane of Helios Reconnaissance Satellite", Aviation Week and Space Technology, 4 June 1990, p. 20.
10. P. B. de Selding, "France Steps Up Its Military, Space Activity, Spending", Space News, 2-8 November 1992, p. 21.
11. "Aerospatiale Delivers Main Optical Imager for Helios", Space News, 17-23 January 1994, p. 12.
12. C. Covault, "CNES, Matra Accelerate Spacecraft, Ariane 5 Tests", Aviation Week and Space Technology, 5 December 1994, p. 22.
13. P.B. de Selding, "French Firm Outlines Helios' Complex Encryption Plan", Space News, 31 May - 6 June 1993, p. 7.
14. P.B. de Selding, "Joxe: France to Share Helios Images with WEU", Space News, 10-16 June 1991, p. 22.
15. P.B. de Selding, "Selling Ultrasharp Images Raises Hackles in France", Space News, 5-11 September 1994, p. 4.
16. P.B. de Selding, "Spy Satellites for Sale", Space News, 13-19 March 1995, pp. 1, 36.
17. "Matra Marconi Proposes Expanded Program for Helios Reconnaissance Satellite", Aviation Week and Space Technology, 20 May 1991, p. 63.
18. P.B. de Selding, "Gulf War Spurs Call for European Spy Satellites", Space News, 11-17 March 1991, p. 3.
19. P.B. de Selding, "French Begin Military Radar Satellite", Space News, 4-10 November 1991, pp. 1, 20.

20. "France Gives NASA Nod for Prime Osiris Role", Space News, 5-11 September 1994, p. 2.
21. C. Lardier, "Matra Veut Rester Maitre De L'Observation", Air & Cosmos, 19 May 1995, p. 38.
22. C. Lardier, "Participation Europeenne Pour Helios 2", Air & Cosmos, 20 January 1995, p. 36.
23. C. Lardier, "Decision Imminente A Bonn Sur Les Satellites Militaires", Air & Cosmos, 21 April 1995, p. 39.
24. Reuter, Le Bourget, 13 June 1995.
25. C. Covault, "Munich Summit To Eye Space Recon Issues", Aviation Week and Space Technology, 26 June 1995, p. 20.
26. C. Lardier, "L'Espagne Abandonne Helios 2", Air & Cosmos, 30 September 1994, p. 31.
27. P.B. de Selding, "Spain Bows Out of Helios' Successor", Space News, 19-25 September 1994, pp. 1, 20.
28. P.B. de Selding, "Matra, Aerospatiale Lift Helios 2 Veil at Committee Hearing", Space News, 21-27 March 1994, p. 11.
29. P.B. de Selding, "Potential Partners Give Helios Follow-on Cool Response", Space News, 28 June - 11 July 1993, p. 5.
30. P.B. de Selding, "Kohl Backs Joint Work On Osiris, Helios 2", Space News, 5-11 December 1994, pp. 4, 21.
31. P.B. de Selding, "About Face: Spain, Italy Join Helios 2 Program", Space News, 16-22 January 1995, pp. 1, 21.
32. P.B. de Selding, "Germans Chafe at Helios Tab", Space News, 23-29 January 1995, pp. 3, 21.
33. N. Usui, "Japan May Include Spy Satellites in Plan", Space News, 24-30 January 1994, p. 14.
34. N. Usui and B. Opall, "Japan Eyes Space for Defense", Space News, 1-7 August 1994, pp. 4, 21.
35. N. Usui, "Group in Japan Recommends Spy Satellites", Space News, 29 August - 4 September 1994, pp. 4, 21.
36. N. Usui, "JDA Seeks Spy Satellite Imagery", Space News, 15-21 May 1995, p. 8.
37. Aviatsiya i Kosmonavtika, March 1993, pp. 41-42.
38. Yu. M. Frumkin, Priroda, April 1993, pp. 72-78.
39. N. Dolgoplov, Komsomolskaya Pravda, 9 July 1993, p. 3.
40. DoD Authorization for FY 1987, House Armed Services Committee, US House of Representatives, 1986, p. 916, Testimony of General Randolph.

41. "USSR Boosts Reconnaissance Capabilities", Aviation Week and Space Technology, 21 January 1985, p. 15.
42. "Statement of Rear Admiral Thomas A. Brooks, U.S. Navy Director of Naval Intelligence", before the Seapower, Strategic, and Critical Materials Subcommittee of the House Armed Services Committee on Intelligence Issues, House of Representatives, 22 February 1989, p. 25.
43. D. Fulghum, "Experts Report Advances in Capability of Soviet Reconnaissance Satellites", Defense News, 14 November 1988, p. 14.
44. C. Covault, "USAF Eyes Advanced Russian Military Reconnaissance Imagery", Aviation Week and Space Technology, 23 May 1994, p. 53.
45. Novosti Kosmonavtiki, 17-31 December 1994, pp. 20-21.
46. Novosti Kosmonavtiki, 10-23 September 1994, p. 44 and 26 March-8 April 1995, pp. 31-32.
47. G. de Briganti, "WEU Study Group Envisions Spy Satellite Program", Space News, 1-7 February 1993, pp. 3, 21.
48. P.B. de Selding, "Europe Eyes Space Sentry", Space News, 26 April - 2 May 1993, pp. 1, 20.
49. P.B. de Selding, "France to Provide Imagery to WEU", Space News, 3-9 May 1993, p. 9.
50. I. Parker, "Peace From Orbit", (Interview with the Director of the WEU Satellite Center), Space, October 1993, pp. 20-22.
51. "Europeans Object to Space Center Plans", Military Space, 13 December 1993, pp. 6-7.
52. "Newsmaker Forum" (Interview with the Director of the WEU Satellite Center), Space News, 15-28 August 1994, pp. 22.
53. P.B. de Selding, "Europeans Help To Cut Costs", Space News, 31 October - 6 November 1994, pp. 4, 21.
54. P.B. de Selding, "WEU Delays Facility Decision", Space News, 21 November - 4 December 1994, p. 3.
55. P.B. de Selding, "Proposed Military Satellite Program Doubtful", Space News, 3-9 April 1995, pp. 4, 45.
56. P.B. de Selding, "WEU Postpones Satellite Decision", Space News, 22-28 May 1995, pp. 3, 21.
57. P.B. de Selding, "WEU Favors European Spy Satellite Program", Space News, 26 June - 2 July 1995, pp. 1, 28.
58. "France's Recon Satellite Will Conduct ELINT Missions", Defense Daily, 31 March 1987, p. 169.
59. P.B. de Selding, "France To Launch Eavesdropping Satellite in '94", Space News, 3-9 February 1992, pp. 1, 28.
60. P.B. de Selding, "France Confirms Work on New Spy Satellite Systems", Space News, 6-19 July 1992, p. 1.

61. "France Advances Space-Based Systems for Military Use", Aviation Week and Space Technology, 20 July 1992, p. 49.
62. "French Will Launch Two Eavesdropping Satellites", Space News, 5-11 June 1995, p. 14.
63. D. Ball and R. Windrem, Soviet Signals Intelligence (SIGINT): Organization and Management, Reference Paper No. 168, Strategic and Defence Studies Centre, The Australian National University, Canberra, September 1989.
64. D. Ball, Soviet Signals Intelligence (SIGINT), Canberra Papers on Strategy and Defence No. 47, Strategic and Defence Studies Centre, The Australian National University, Canberra, 1989.
65. C. Andrew and O. Gordievsky, KGB, The Inside Story, Harper Collins, Publisher, 1990, p. 609.
66. J. Anderson, "GAO Audits Soviet Spy Satellites", Washington Post, 11 February 1985, p. C12.
67. 1989 Joint Military Net Assessment, Joint Chiefs of Staff, US Government, 1989, pp. 11-12.
68. Pravda Ukrainy, 10 April 1993, p. 1.
69. Krasnaya Zvezda, 30 July 1991, p. 4.
70. G.M. Chernyavskiy, et al, "The Recent Fragmentations of LEO Upper Stages", Paper IAA-94-IAA.6.5.696, 45th Congress of the International Astronautical Federation, October 1994.
71. Soviet Military Power 1985, Department of Defense, US Government Printing Office, April, 1985, p. 53.
72. Soviet Military Power 1988, Department of Defense, US Government Printing Office, April, 1988, p. 63.
73. G. C. Wilson, "Antisatellite Effort Needed, Senate Is Told", Washington Post, 24 April 1987.
74. R. S. Cooper, Director, Defense Advanced Research Projects Agency, in testimony before a Subcommittee of the Committee on Appropriations, US House of Representatives, 23 March 1983.
75. J. Bussert, "Wartime Needs Give Direction to Soviet C<sup>3</sup>I Technology", Defense Electronics, May 1985, p. 155.
76. "Analysis of Changes to the Baku", Jane's Defense Weekly, 6 August 1988, p. 225.
77. N. L. Johnson, The Soviet Year in Space 1990, Teledyne Brown Engineering, 1991, p. 90.
78. Novosti Kosmonavtiki, 25 September - 8 October 1993, pp. 31-32.
79. Segodnya, 7 February 1995, p. 3.
80. Use of Nuclear Power Sources in Outer Space, Report A/AC.105/C.1/WG.5/L.24/Add.2, Committee on the Peaceful Uses of Outer Space, General Assembly, United Nations, 26 February 1990.

81. Nazarenko, A.I., et al, "Analysis of Fragmentation Situation in the Neighborhood of Russian Satellites with Nuclear Power Sources", Orbital Debris Monitor, July 1995.
82. L. David, "Russian Satellites Suspected as Space Debris Source", Space News, 13-19 February 1995, p. 19.
83. "ESAT", Flight International, 18-24 January 1995, p. 44.
84. "CNES Urged To Finance Missile Warning Study", Space News, 16-22 January 1995, p. 2.
85. N. Usui, "U.S., Japan Discuss Sharing Missile Warnings", Space News, 23-29 January 1995, p. 6.
86. B. Kagan, Soviet ABM Early Warning System (Satellite-based Project M), Delphic Associates, Inc., 1991.
87. P. Podvig, "The Operational Status of the Russian Space-Based Early Warning System", Science & Global Security, Vol. 4, 1994, pp. 363-384.
88. Pravda, 15 April 1991, p. 8.
89. Krasnaya Zvezda, 14 March 1991, p. 4.
90. B.S. Skrebushevskiy, et al, "The Principles of the Development of Space Equipment for SPRN", Voyennaya Mysl, June-July 1992.
91. Novosti Kosmonavтики, 1-17 January 1993, pp. 19-21, and 1-14 March 1993, pp. 17-19.
92. J. Bilbro, et al, "Report of Visit to Selected Russian Laboratories" (18-30 October 1992), NASA Optics Technology Team.
93. P.S. Clark, "Russia's Geosynchronous Early Warning Satellite Program", Jane's Intelligence Review, February 1994, pp. 61-64.
94. Pravitelstvennyy Vestnik, February 1992, p. 5.
95. "Early Warning Center Planned", Space News, 24 February - 1 March 1992, p. 2.
96. "Washington Roundup, Bombs Away", Aviation Week and Space Technology, 24 February 1992, p. 25.
97. J.M. Lenorovitz, "U.S., Russia To Share Missile Warning Data", Aviation Week and Space Technology, 11 April 1994, pp. 24-25.
98. W.B. Scott, "Russian Pitches Common Early Warning Network", Aviation Week and Space Technology, 9 January 1995, pp. 46-47.
99. S. Weber, "Obstacles Remain for Joint Military Research Program", Space News, 24-30 October 1994, p. 17.
100. C. Privor, "Joint Efforts Could Strengthen Defense Capabilities", Space News, 14-27 August 1995, p. 11.

101. ITAR-TASS, Moscow, 20 October 1993.
102. J.M. Lenorovitz, "Joint Flight To Gather ICBM Tracking Data", Aviation Week and Space Technology, 18 October 1993, pp. 96-97.
103. V. Kiernan, "BMDO Shortfall May Delay U.S. - Russian Skipper Launch", Space News, 13-19 December 1993, p. 22.
104. L.H. Caveny, "BMDO Projects with Russian Institutes", International Conference of Problems Related to the Global Protection System from Ballistic Missiles, 22-24 November 1993.
105. L. Henares, Towards a European Space Observation System Colloqui, San Augustin, 24-25 March 1995.
106. For a more in-depth discussion of this topic and the history of Soviet space defense capabilities see N.L. Johnson, Soviet Military Strategy in Space, Jane's Publishing Company, London, 1987.
107. Nezavisimaya Gazeta, 21 November 1991, p. 5.
108. The Soviet Space Challenge, Department of Defense, US Government Printing Office, November, 1987, p. 11.
109. Military Forces in Transition 1991, Department of Defense, US Government Printing Office, 1991, p. 37.
110. Krasnaya Zvezda, 5 October 1990, p. 2.
111. Sovetskaya Rossiya, 5 August 1990, p. 4.
112. Der Spiegel, 8 February 1988, pp. 130-138.
113. Komsomolskaya Pravda, 24 October 1989, p. 1.
114. "Sary Shagan and Kyshtym, A Visit to Soviet Nuclear Facilities", Science and Global Security, Vol. 1, No.'s 1-2, pp. 165-170.
115. "Soviets Display Laser Facility at Sary Shagan", Aviation Week and Space Technology, 17 July 1989, p. 27.
116. Rep. R. Carr, "Soviets Taking Wraps Off Secrecy", Defense News, 28 August 1989, p. 30.
117. "Soviet Union Developing Laser Antisatellite Weapon", Aviation Week and Space Technology, 16 June 1980, pp. 60-61.
118. "Heflin Says Soviets Have Operational Anti-Satellite Laser", Defense Daily, 28 July 1981, p. 146.
119. Krasnaya Zvezda, 17 August 1989, p. 3.
120. Sovetskaya Litviya, 8 September 1989, p. 3.
121. Izvestiya, 13 December 1991, p. 3.

122. Nezavisimaya Gazeta, 26 February 1992, p. 2.
123. Nezavisimaya Gazeta, 25 September 1991, p. 6.
124. Zemlya I Vselennaya, July-August 1992, pp. 18-23.
125. C. Wachtel, "Comment La Russie A Perdu La 'Guerre Des Etoiles' ", La Recherche, March 1995, pp. 270-279.
126. "Russians Alter MiG-31 for ASAT Carrier Role", Aviation Week and Space Technology, 17 August 1992, p. 63.
127. A. I. Nazarenko, et al, "The Space-Temporal Variations of the Upper Atmospheric Density Derived From Satellite Drag Data", Advances in Space Research, Vol. 11, No. 6, 1991, pp. 155-160.
128. Novosti Kosmonavtiki, 20 October - 4 November 1994, pp. 48-49.
129. For example, see N. L. Johnson, The Soviet Year in Space 1989, Teledyne Brown Engineering, 1990, p. 88.
130. "Soviets Orbit ABM Test Satellite", Defense Daily, 29 October 1981, p. 284.
131. G. E. Perry, "A Possible Mission for the Sub-Set of Cosmos Satellites Which Produce Additional Objects During Their Active Phase", First European Conference on Space Debris, April, 1993.
132. ITAR-TASS, 3 August 1994.





## **SECTION 7. SPACE-RELATED LEGAL DOCUMENTS**

**7.1 Decree No. 4878-1 of the Russian Supreme Soviet: "Measures to Stabilize the Situation in Space, Science, and Industry" (adopted 27 April 1993)**

With a view to preserving the intellectual, economic, and defense potential of space, science, and industry, the Russian Federation Supreme Soviet decrees that:

**1. The Russian Federation shall:**

make provision in the Russian Federation's draft budgetary system for the next fiscal year for appropriations to be allocated to the Russian space program as a separate line item to be indexed quarterly;

submit to the Russian Federation Supreme Soviet by 1st June 1993 the draft Russian federal space program for space systems, complexes, and means with scientific, economic, and defense roles;

define the Russian Space Agency as the state customer for space systems, complexes, and means with scientific and economic roles, and - in conjunction with the Russian Federation Ministry of Defense - for space systems, complexes, and means used for both civilian and military purposes;

stipulate the direct allocation to the Russian Space Agency of appropriations for research and development work, the purchase and operation of space equipment, capital construction, the maintenance of groundbased space infrastructure installations, and other work under the Russian Federal Space Program to be carried out by the Russian space agency;

supply space projects financed out of the Russian Federation budget - specifically, space systems, complexes, and means with scientific and economic roles - with raw and other materials, equipment, components, and other material and technical resources under the procedure stipulated for state orders for arms and military equipment in accordance with the Russian Federation law "On Deliveries of Output and Goods for State Needs";

define a procedure for promoting the implementation of space projects using the funds of enterprises, organizations, and citizens, including the granting to them of state guarantees, soft loans, tax concessions, and other necessary measures;

elaborate a program of structural transformations in space science and industry, including the creation of federal space centers based on leading design bureaus and scientific research institutes as well as holding and joint-stock companies, taking account of their targeted financing, including funding from conversion funds;

examine the remuneration system for people employed in the space complex, taking account of the unified wage system and average pay levels in the Russian Federation;

elaborate a plan for the further utilization of groundbased space infrastructure - primarily the Plesetsk space center - taking account of the socio-economic aspects of the development of the regions in question;

take measures to strengthen social protection for space center works and specialists at enterprises and organizations engaged in the testing and operation of space equipment;

take the necessary measures to preserve the existing science and production links in the sphere of space activity in the CIS, including consultations with the Republic of Kazakhstan to clarify the status of and prospects for the further joint use of the Baikonur space center;

elaborate and ensure implementation of a unified scientific, technical, and economic policy when concluding and executing international agreements on space research and the use of space, including commercial space projects.

2. The Soviet of the Republic of the Russian Supreme Soviet's Commission for Transportation, Communications, Information Technology, and Space, jointly with the Russian Space Agency, the Russian Academy of Sciences, and other interested departments, shall prepare proposals for the creation of a Russian space fund as an independent organization to concentrate funding from internal and external sources with a view to stimulating basic research, forming financial insurance reserves, introducing space technology into the national economy and supporting measures to utilize the achievements of space science for public education and cultural purposes.
3. The Russian Federation Supreme Soviet Committee for International Affairs and Foreign Economic Relations, jointly with interested chamber standing commissions and Russian Federation Supreme Soviet committees, shall prepare materials on international agreements in the sphere of space activity with the participation of the Russian Federation for examination by the Russian Federation Supreme Soviet.
4. A provisional deputies' group of representatives from interested chamber standing commissions and Russian Federation Supreme Soviet committees shall be set up with a view to strengthening parliamentary control of space activity. The group's work shall be organized by the Soviet of the Republic's Commission for Transport, Communications, Information Technology, and Space.

## **7.2 Decree 4879-1 of the Russian Supreme Soviet: "On the Priorities of Russian Federation Space Policy" (adopted 27 April 1993)**

For over 30 years space science in our country has served the interests of the state. Without it, communications and television broadcasting, navigation and meteorology, surveying and cartography, and many other sectors of the national economy would be inconceivable. Space technologies are something no progressive power can do without. It is hard to overestimate the importance of space systems in maintaining the country's defense capability.

Realizing its responsibility for preserving Russia's space potential and the extensive application of this potential in resolving the pressing problems of citizens and society as a whole, the Russian Federation Supreme Soviet considers it necessary to state the priorities of space policy that are to be enshrined in Russian Federation legislation and consistently implemented in the day-to-day practice of the state administration of space activity.

1. Space activity in the Russian Federation is to be implemented with a view to ensuring the prosperity of citizens, the development of the Russian Federation, the strengthening of its security and also resolving the global problems of humanity.

Russian space science should ensure:

- the equal right of Russian Federation enterprises, organizations, and citizens to participate in space activity and enjoy its results;
- access to information about space activity;
- restriction of monopolies and the development of entrepreneurial activity;
- independent expert analysis of space projects and programs;
- safety in space activity, including the protection of the environment.

2. Russia's federal space program is being organized in line with the requirements and economic resources of society and the state.

National economic space projects should be designed to tackle tasks with the greatest socio-economic impact, primarily in the development of networks for receiving, processing and transmitting information, communications, television broadcasting, environmental monitoring, and studying natural resources.

Work of an exploratory nature enabling fundamentally new tasks to be set and tackled, and also applied work commissioned by specific consumers, should be given priority in scientific space research.

Space activity for military purposes should be concentrated primarily on the use of space systems for military command and control, communications, intelligence, and other types of support for the armed forces.

3. Structural transformations in space science are to be implemented taking into account the specific features of space science and industry and are to include the flotation and privatization of profitable production facilities. At the same time, unique testing equipment, and also space infrastructure installations with state significance, should remain within state ownership and be made available for use by interested enterprises and organizations. During the economic reforms, it is extremely important not to forfeit the intellectual property of enterprises, organizations, and citizens taking part in space hardware and space technology developments.

The specific features of space activity - the intermingling of science and production, the protracted investment cycle and high degree of commercial risk, the difficulty of obtaining a direct return on invested capital, and the close link between domestic and foreign capital - require special economic approaches. Taking world experience into account, it is necessary to formulate a special system for granting loans to, levying taxes on, and offering state guarantees to enterprises and organizations working on space projects.

Strengthening Russia's positions in the world space market presupposes attracting foreign investment backed up by appropriate state guarantees, and also guarantees employing funds from the Russian enterprises and organizations concerned.

4. The Russian Federation Supreme Soviet favors cooperation in opening up space with CIS member countries and the preservation and development of established scientific and production ties. Further steps must be taken to implement the Minsk agreement on joint action to study and exploit space, primarily as regards mechanisms for adopting mutually advantageous interstate space projects and their shared financing by the states, enterprises, and organizations concerned.
5. In issues of international relations connected with space activity, state policy is designed to support domestic enterprises and organizations, deepen international cooperation and integration in opening up space on a mutually advantageous basis, and ensure the fulfillment of Russia's obligations under international agreements.

**7.3 Decree No. 5663-1 of the Russian House of Soviets: "Russian Federation Law on Space" (adopted 20 August 1993)**

The mastery of space, whose beginning was laid in Russia, is affording new prospects for world civilization. In the Russian Federation the exploration and use of space, including the moon and other celestial bodies, are some of the most important directions in activity in the interests of citizens, society, and the state.

This law is directed to ensuring the juridical regulation of space activity and stimulates the application of the potential of space science and industry for solving socioeconomic, scientific-technical, and defense problems of the Russian Federation.

**Section I. General Principles**

**Article 1. Legislation of the Russian Federation on Space Activity**

1. This law establishes the juridical and organizational principles of space activity under the jurisdiction of the Russian Federation.
2. Space activity under the jurisdiction of the Russian Federation also is regulated by other legislative and other norm-setting actions of the Russian Federation published in accordance with the Constitution of the Russian Federation and this Law.

**Article 2. Space Activity Concept**

1. For the purposes of this law the term "space activity" means any activity associated with the direct performance of work on the exploration and use of space, including the moon and other celestial bodies.

Space activity includes: scientific space research; space communication, including television and radio broadcasting using satellite systems; remote sensing of the Earth from space, including ecological monitoring and meteorology; use of satellite navigational and topogeodetic systems; manned space flights; production of materials and other products in space; other types of activity carried out using space technology.

2. Space activity includes the creation (including the development, fabrication, testing), as well as the use and transfer of space equipment, space technologies, other products and services necessary for implementing space activity.

**Article 3. Objectives and Tasks of Space Activity**

1. Space activity is carried out for the purpose of enhancing the well-being of the citizens of the Russian Federation, the further development of the Russian Federation and ensuring its safety, and also for the purpose of solving the global problems of mankind.
2. The principal tasks of space activity under the jurisdiction of the Russian Federation are: ensuring access to space; study of the Earth and space; development of science, equipment, and technologies favoring an increase in economic efficiency; ensuring the defense capability of the Russian Federation and monitoring compliance with international agreements relating to armaments and armed forces.

#### **Article 4. Space Activity Principles**

1. Space activity is carried out in conformity to the following principles: an equal right of organizations and citizens of the Russian Federation to participation in space activity; accessibility to information on space activity; use of the results of space activity in the interests of users with adherence to the rights of organizations and citizens participating in space activity; introduction of the advances in space science and equipment in the economy; restriction of monopolistic activity and development of entrepreneurial activity; independence of expert evaluation relative to space activity matters; assurance of safety in space activity, including safeguarding of the environment; participation in international cooperation in the space activity field; international responsibility of the state for space activity carried out under its jurisdiction.
2. For the purpose of ensuring strategic and ecological safety in the Russian Federation the following are forbidden: putting into an orbit around the Earth or placement in space by any means whatsoever of nuclear weapons and any other forms of weapons of mass destruction; tests of nuclear weapons and any other types of weapons of mass destruction in space; use of space objects and other space equipment as means for modifying the environment for military or other hostile purposes; intentional creation of a direct threat for the safety of space activity, including for the safety of space objects; harmful pollution of space, leading to unfavorable environmental changes, including intentional destruction of space objects in space.

Any other space activity under the jurisdiction of the Russian Federation banned by international agreements of the Russian Federation also is forbidden.

3. Space activity, as well as the dissemination of information on space activity, are accomplished with adherence to the requirements on protection of the rights of intellectual property, state, including military, and commercial secrets established by legislation of the Russian Federation.
4. General information on space activity not falling under the provisions of point 3 of this article, including information on: plans for launchings of space objects and changes in these plans; space projects and the course of their implementation; budget appropriations for space activity; incidents and occurrences during the implementation of space activity, and on losses sustained in such occurrences, are disseminated without restrictions.

#### **Section II. Organization of Space Activity**

##### **Article 5. Competence of State Governmental and Administrative Bodies**

1. In the Russian Federation space activity is under the management of federal state governmental and administrative bodies
2. The Supreme Soviet of the Russian Federation determines the space policy of the Russian Federation including: it receives legislative bills regulating space activity; it receives the Federal Space Program of Russia; it oversees implementation of the Federal Space Program of Russia and the expenditure of state resources allocated for space activity; it ratifies international agreements of the Russian Federation on space activity matters; it solves, within the limits of its competence, other problems arising in the implementation of space activity.
3. The President of the Russian Federation is responsible for implementation of the space policy of the Russian Federation, including: he issues decrees and orders necessary for the implementation of space activity; he directs the activity of the Council of Ministers - the Government of the Russian Federation - in implementation of

the Federal Space Program of Russia and other matters related to the performance of space activity; he solves, within the limits of his competence, other problems arising in the implementation of space activity.

4. The Council of Ministers - the Government of the Russian Federation - ensures direction of space activity, including: it issues decrees and orders necessary for the implementation of space activity; it examines the draft of the Federal Space Program of Russia presented by the Russian Space Agency, Ministry of Defense of the Russian Federation, Russian Academy of Sciences and other state placers of orders for work on developing and using space technology; it presents to the Supreme Soviet of the Russian Federation a draft of the Federal Space Program of Russia and proposals on the financing of space activity; it approves the Regulations for the Russian Space Agency; it implements measures for protecting the interests of the Russian Federation, as well as Russian organizations and citizens in the space activity field; it solves, within the limits of its competence, other problems arising in the implementation of space activity.
5. The republics forming part of the Russian Federation, autonomous oblast, autonomous okrugs, krays, and oblasts, the cities of Moscow and St. Petersburg participate with full equal rights in the regulation of space activity within the framework provided for by this Law.

#### **Article 6. Russian Space Agency**

1. The Russian Space Agency is the body of the federal executive authority responsible for the implementation of space activity for scientific and economic purposes.
2. The Russian Space Agency within the limits of its competence: works out a draft of the Federal Space Program of Russia in collaboration with the Ministry of Defense of the Russian Federation, Russian Academy of Sciences and other placers of orders for work on the development and use of space equipment; draws up and places state orders for work on developing and using space equipment for scientific and economic purposes, including for work on international space projects; participates jointly with the Ministry of Defense of the Russian Federation in the placement of state orders for work on the development and use of space equipment employed for both scientific and economic purposes and for the purposes of defense and safety of the Russian Federation; for scientific and economic purposes ensures, in collaboration with the Ministry of Defense of the Russian Federation and other ministries and departments of the Russian Federation, operation, maintenance and development of surface and other facilities of the space infrastructure; issues licenses for different types of space activity; organizes certification of space equipment; supplies space activity with the necessary norm-setting and technical documentation; in collaboration with the appropriate state services ensures the safety of space activity; interacts with organizations and bodies in foreign states, as well as with international organizations, on matters related to space activity and concludes corresponding international agreements; performs other functions specified by the Council of Ministers - the Government of the Russian Federation
3. In order to implement its functions, taking into account the interests of the subjects of the Russian Federation with respect to the use of the results of space activity, the Russian Space Agency can establish its territorial bodies.

#### **Article 7. Space Activity for Purpose of Defense and Safety of Russian Federation**

1. Space activity for the purposes of defense and safety of the Russian Federation is carried out by the Ministry of Defense of the Russian Federation, responsible for carrying out an anticipatory program and annual plans for work on developing and using military space equipment, in collaboration with other ministries and departments of the Russian Federation.



2. The Ministry of Defense of the Russian Federation within the limits of its competence: draws up drafts of an anticipatory program and annual plans for work on developing and using military space equipment, and also in collaboration with the Russian Space Agency - space equipment used for both scientific and economic purposes and for the purposes of defense and safety of the Russian Federation; prepares and places state orders for work on developing and using military space equipment, and also in collaboration with the Russian Space Agency - space equipment used for both scientific and economic purposes, as well as for the purposes of defense and safety of the Russian Federation; implements the use of space technology for the purposes of defense and safety of the Russian Federation; implements operation of space equipment for scientific and economic purposes on a contractual basis; in collaboration with the Russian Space Agency and other ministries and departments of the Russian Federation ensures maintenance and further development of surface and other facilities of the space infrastructure; supplies space activity with the necessary norm-setting and technical documentation; participates in the certification of space technology on a contractual basis; ensures, in collaboration with the appropriate state services, safety in space activity; performs other functions assigned by the Council of Ministers - the Government of the Russian Federation.
3. The Ministry of Defense of the Russian Federation in cases directly provided for by legislation of the Russian Federation, has the right to mobilize any facilities of the space infrastructure, including space technology.
4. The Ministry of Defense of the Russian Federation has the right to transfer temporarily unused facilities of the space infrastructure under its control to the Russian Space Agency on a contractual basis for use in carrying out space activity for scientific and economic purposes.

#### **Article 8. Federal Space Program of Russia**

1. The Federal Space Program of Russia is a document on whose basis state orders are prepared for the development and use of space equipment for scientific and economic purposes. The procedures for interaction between the Russian Space Agency and the Ministry of Defense of the Russian Federation in working out and collating the Federal Space Program of Russia and the long-term program and annual work plans for developing and using military space equipment is defined by legislation of the Russian Federation.
2. The Federal Space Program of Russia is drawn up with allowance for: established goals, tasks and principles of space activity; interests of subjects of the Russian Federation; economic situation in the country; status of space science and industry; need for multisided development of the space and surface segments of the space infrastructure; interests of users and producers of space equipment and space technologies; status and tendencies in development of cosmonautics; competitive situation in the world space market; adopted international obligations of the Russian Federation and the tasks involved in the broadening of international cooperation.
3. The Federal Space Program of Russia is worked out in accordance with the results of competitions among the space projects presented by the interested ministries and departments of the Russian Federation, organizations, and citizens.

The procedures and conditions for carrying out competitions among space projects proposed for scientific and economic purposes are determined by the Russian Space Agency with the participation of the Russian Academy of Sciences and other placers of orders for developing and using space equipment.

4. General information on the Federal Space Program of Russia and an annual report on the course of its implementation are published in the press.

#### **Article 9. Licensing of Space Activity**

1. This Law establishes the permissive (licensing) procedures for implementation of space activity for scientific and economic purposes.
2. Licensing is required for space activity of organizations and citizens of the Russian Federation or the space activity of foreign organizations and citizens under the jurisdiction of the Russian Federation if such activity includes testing, manufacture, storage, preparation for launching, and launching of space objects and also the control of space flights.
3. The types, forms, and times of validity of licenses, conditions, and procedures for their issuance, denial of their issuance, suspension or termination of their validity, and also other licensing problems, are regulated by legislation of the Russian Federation.
4. The implementation of space activity by an organization or citizen without a license or with intentional violation of the licensing conditions is answerable for, as provided for by legislation of the Russian Federation.
5. The actions of state bodies with respect to the licensing of space activity can be appealed to a court or an arbitration tribunal.

#### **Article 10. Certification of Space Equipment**

1. Space equipment, including space objects, surface and other facilities of the space infrastructure developed for scientific and economic purposes, must be checked for correspondence to the requirements established by legislation of the Russian Federation (certifications). Certifications also may be required for the equipment employed in the development and use of space equipment.
2. A certificate is issued for each item of space equipment upon completion of the certification procedure. The types, forms, and times of validity of the certificates, conditions, and procedures for their issuance, denial of their issuance, suspension or termination of their validity, as well as other certification matters, are regulated by legislation of the Russian Federation.
3. The certification bodies, manufacturers of space equipment, and corresponding responsible parties guilty of violating the rules for the certification of space activity bear the accountability established by legislation of the Russian Federation.

#### **Article 11. Expert Evaluation of Space Activity Matters**

1. Decisions on the following matters related to the implementation of space activity are made on the basis of expert evaluations: inclusion of the project in the Federal Space Program of Russia; adoption of the Federal Space Program of Russia; issuance of licenses for the implementation of space activity; issuance of certificates for space equipment, and also for equipment employed in developing and using space equipment; assignment of space equipment and space technologies to the category of products whose export is forbidden or restricted; drawing conclusions concerning the results of competitions among space projects; determination of the reasons for incidents occurring during the implementation of space activity; action on other matters determined by the Council of Ministers - the Government of the Russian Federation.
2. In order to make an expert evaluation the Supreme Soviet of the Russian Federation, the Council of Ministers - the Government of the Russian Federation, Russian Space Agency or other body making a decision on matters

related to the implementation of space activity organizes expert commissions of specialists disinterested in the results of the expert evaluation.

3. The procedures for organization and work of the expert commissions are defined by legislation of the Russian Federation.
4. The conclusion drawn by an expert commission has no mandatory force for a body making a decision on matters related to the implementation of space activity. The responsibility for such a decision, including for a decision not consistent with the conclusion of the expert commission, is borne by the director of the body making the decision. The members of the expert commission bear responsibility for the correctness and soundness of their conclusions.

### **Section III. Economic Conditions for Space Activity**

#### **Article 12. Financing of Space Activity and Foreign Investments**

1. The financing of space activity for scientific and economic purposes from the resources of the republic budget of the Russian Federation is accomplished on the basis of the Federal Space Program of Russia and is taken into account in the republic budget of the Russian Federation as an individual item. The financing of space activity for the purpose of the defense and safety of the Russian Federation is provided for in the republic budget of the Russian Federation in the expenditures for defense.
2. The financing of space activity from the resources of the republic budget of the Russian Federation is accomplished purposefully through the state placers of orders for work for developing and use of space equipment and is distributed among those performing work in accordance with state contracts. A state placer of an order and the performer of the work have the right to draw upon nonbudgeted sources of financing, including their own resources, if this does not contradict the purposes of the space project.
3. Organizations and citizens participating in the implementation of space projects under the established procedures may be afforded state guarantees, preferred credits, tax and other necessary financial incentives.
4. Foreign investments in space activity associated with implementation of the Federal Space Program of Russia can be guaranteed by the resources in the budget of the Russian Federation, property or other belongings of the Russian Federation. Foreign investments in the space activity of organizations and citizens of the Russian Federation can be guaranteed by their own resources or by intellectual or other property.

#### **Article 13. Russian Space Fund**

1. The Russian Space Fund is established for supporting and further development of space science and industry.
2. The resources of the Russian Space Fund are formed from the following sources: appropriations from the republic budget of the Russian Federation allocated purposefully as part of the resources for the Federal Space Program of Russia; nonbudgeted funds formed by state placers of orders for work on the development and use of space technology for scientific and economic purposes; part of the profit received by organizations and citizens due to the financial incentives afforded them with respect to taxation when implementing space activity; profit received in the course of implementation of space projects financed by the Russian Space Fund; insurance payments made by organizations and citizens engaged in space activity by way of mandatory or voluntary insurance; voluntary contributions of Russian and foreign organizations and citizens. The procedures for forming and use of the resources of the Russian Space Fund are defined by the Regulations of the Russian Space Fund.

3. The resources of the Russian Space Fund are directed to the financing of the Federal Space Program of Russia by agreement with the Russian Space Agency and others placing orders for work on development and use of space equipment, for the support of innovative and conversion space projects, and measures for use of the results of space activity, including for the purposes of development of science, education, and culture. The priority in the distribution of the resources of the Russian Space Fund is for work of a research character making it possible to solve fundamentally new problems, as well as projects with a high economic, social and other effectiveness. The resources of the Russian Space Fund also are used in insuring the risks associated with space activity and elimination of the consequences of incidents occurring during the implementation of such activity.
4. The Russian Space Fund operates on the basis of regulations approved by the Council of Ministers - the Government of the Russian Federation - by agreement with the Supreme Soviet of the Russian Federation

#### **Article 14. Development of Space Equipment**

1. A state order for the development of space equipment is prepared and placed on the basis of the Federal Space Program of Russia, the long-term program, and annual plans for work on developing and using military space equipment.
2. Work under a state order is carried out in accordance with the technical specifications approved by the state placer of the order, which is the basis for concluding a state contract between the state placer of the order and the performer of the work. The performer of the work under a state order bears the responsibility for meeting the requirements of the technical specifications issued by the state placer of the order, including for satisfying the requirements of the technical specifications with their coperformers, relative to whom it performs the functions of the state placer of the order. The performer of work under a state order is obliged to exert primary supervision in all stages of development and use of space equipment on a contractual basis.
3. The rights of ownership to space equipment pass to the placer of the order from the moment of signing of the document certifying delivery and acceptance of the work unless otherwise stipulated in the corresponding contract. The rights of organizations and citizens participating in the development of space equipment, with respect to subsequent use of such equipment, are defined in contracts concluded between these organizations and citizens and those placing the work orders.
4. An organization with the participation of foreign capital may be the performer of work under a state order if the fraction of foreign capital in its fund account does not exceed 49 percent. The performer of work under a state order has the right to bring in foreign organizations and foreign citizens as coperformers and bears responsibility for their performance of their obligations.

#### **Article 15. Use and Transfer of Space Equipment**

1. Space equipment can be used as intended after it is put into operation. The procedures for use of space equipment for the purposes of tests and putting it into operation are defined by legislation of the Russian Federation.
2. Space equipment is operated by the owner of such equipment or other organizations and citizens by contract with the owner.
3. The components of space equipment may belong to several organizations and citizens if this does not violate the technological rules of functioning of such equipment. The procedures for operation of space equipment,

whose components belong to several organizations and citizens, is defined by contracts among these organizations and citizens.

4. An organization operating space equipment, being federally owned, on a contractual basis ensures the possibility of use of such equipment by any interested organizations and citizens. When concluding a contract for the use of space equipment which is federally owned preference is given to projects under the Federal Space Program of Russia and also to organizations and citizens of the Russian Federation proposing the most advantageous conditions for such use.
5. Space equipment taken out of operation can be conveyed to organizations whose principal activity is directed to the use of the results of space activity for the purposes of education and culture. Such equipment also can be used by organizations or citizens on a contractual basis.

#### **Article 16. Use of Space Technologies and Results of Space Activity**

1. Space equipment is used and transferred with allowance for the rights of intellectual property, safeguarded by legislation of the Russian Federation.
2. The performance of work on development of space technology, including under a government order, does not oblige the performer to convey technologies to the placer of the order if it is not provided for in the contract between the placer of the order and the performer.
3. The procedures and conditions for use of the space technologies developed when performing work on development and use of space equipment, whose juridical protection is not provided for in legislation of the Russian Federation, is defined on the basis of contracts between interested organizations and citizens.
4. The rights of ownership to a material product created in space belong to the organizations and citizens having property rights to the components of the space equipment with whose use this product was developed unless otherwise provided for by the corresponding contracts. The rights of ownership to an information product developed as a result of space activity belong to the organizations and citizens creating such an information product unless otherwise provided for in the corresponding contracts. The property rights of other organizations and citizens participating in space activity, including by rendering transportation and other services, are defined by the corresponding contracts.

#### **Section IV. Space Infrastructure**

##### **Article 17. Space Objects**

1. The space objects of the Russian Federation must be registered and must have markings attesting that they belong to the Russian Federation.
2. The Russian Federation retains jurisdiction and control over the space objects registered in it while these objects are on the Earth, in any stage of spaceflight or presence in space, on celestial bodies, as well as after return to the Earth beyond the jurisdiction of any state.
3. The rights of ownership to space objects remain unaffected during the presence of these objects on the Earth, as well as in any stage of spaceflight or presence in space, on celestial bodies, and also after return to the Earth if not provided otherwise by international agreements of the Russian Federation.

4. If a space object is constructed by Russian organizations and citizens jointly with foreign states, organizations and citizens, or international organizations the matters relating to the registry of such an object, jurisdiction and control over it, as well as the matter of rights of ownership of such a space object, are solved on the basis of appropriate international agreements.
5. The rights of jurisdiction and control of space objects, as well as the ownership rights to such an object, do not affect the juridical status of the zone (sector) of space, surface or deep layers of a celestial body occupied by it. Rules mandatory for Russian and foreign organizations and citizens may be established for the immediate neighborhood of a space object of the Russian Federation within the limits of the minimum necessary zone for ensuring the safety of space activity.

#### **Article 18. Surface and Other Space Infrastructure Facilities**

1. The surface and other space infrastructure facilities of the Russian Federation include: cosmodromes; launch pads and launch apparatus; command-measuring complexes; space object flight control centers and points; stations for the reception, storage, and processing of data; bases for the storage of space equipment; landing regions for separated parts of space objects; special sites for the landing of space objects and takeoff-landing strips; facilities of an experimental base for final testing of space equipment; centers and equipment for the training of cosmonauts; other surface structures and equipment used in implementing space activity. The surface and other space infrastructure facilities, including mobile facilities, are such to that degree to which they are used for supporting or implementing space activity.
2. Surface and other space infrastructure facilities, being of federal ownership, are under the management of the state organizations operating them. The transfer of surface and other space infrastructure facilities which are federally owned to the management, ownership, or lease of other organizations is allowed under the procedures established by legislation of the Russian Federation.
3. The allocation of land sectors for surface and other space infrastructure facilities and the alienated zones adjacent to them is accomplished by bodies of the state authority and administration of subjects of the Russian Federation, as well as by local self-administration bodies in accordance with legislation of the Russian Federation. The procedures and conditions for the use of such land sectors are determined by contracts among the appropriate bodies of state authority and administration and organizations operating surface and other space infrastructure facilities.
4. Activity in use of surface and other space infrastructure facilities by organizations and citizens of the Russian Federation beyond the jurisdictional limits of any state is carried out in accordance with this law. Such activity of organizations and citizens of the Russian Federation in territories under the jurisdiction of a foreign state is carried out in accordance with the legislation of that state if this does not contradict this Law.

#### **Article 19. Spaceflight Control**

1. Control of space flights in all stages from the launch of a space object of the Russian Federation to termination of the flight is performed by the organizations operating surface and other space infrastructure facilities.
2. The launch and landing of space objects of the Russian Federation are accomplished in predesignated regions determined in coordination with the corresponding bodies of state authority and administration. In the event of incidents, including accidents and catastrophes occurring during implementation of space activity, the landing of the space objects of the Russian Federation can be accomplished in other regions with notification of the appropriate bodies of state authority and administration.

3. The maneuvering of the space objects in the air space of the Russian Federation is accomplished with allowance for the requirements of the legislation regulating use of the air space of the Russian Federation.
4. A space object of a foreign country may make a one-time harmless flight through the air space of the Russian Federation for the purpose of launching such an object into an orbit around the Earth or beyond into space, and also for the purpose of its return to Earth under the condition of advance notification of the appropriate services of the Russian Federation with respect to the time, place, trajectory, and other conditions of such a flythrough.
5. The Russian Space Agency, in collaboration with the Ministry of Defense of the Russian Federation, provides information on the launching and landing of space objects of the Russian Federation to the appropriate bodies of state authority and administration of the Russian Federation, and in cases of necessity also informs interested foreign countries and international organizations. In the case of launching, landing or ending of the lifetime of space objects of the Russian Federation beyond its borders the corresponding services of the Russian Federation perform their functions in coordination with competent bodies of the interested foreign countries.

#### **Article 20. Cosmonauts and Crews of Manned Space Objects**

1. Citizens of the Russian Federation expressing the desire to participate in space flights and meeting the established professional and medical requirements are selected for training and making space flights on the basis of a competition. The procedures and conditions for the competition are determined by the Russian Space Agency and the Ministry of Defense of the Russian Federation with the participation of other placers of orders for work on the development and use of space equipment and are published in the press.
2. The procedures for the training of cosmonauts, the formation of crews of manned space objects, and the approval of the flight program, as well as the rights and obligations of cosmonauts, payment for their work, and other conditions of their professional activity, are determined by contracts in accordance with legislation of the Russian Federation.
3. A citizen of the Russian Federation is designated as crew commander of a manned space object of the Russian Federation. The crew commander of a manned space object of the Russian Federation is delegated the completeness of authority necessary for implementing a space flight, leadership of the crew, and other individuals participating in the flight. The crew commander of a manned space object of the Russian Federation within the limits of his powers bears responsibility for carrying out the flight program, safety of the crew and other individuals participating in the flight, safeguarding of the space object and the property present in it.
4. The Russian Federation retains jurisdiction and control over any crew of a manned space object registered in the Russian Federation during presence of this object on the Earth, in any stage of the flight or presence in space, on celestial bodies, including beyond the limits of the space object, as well as upon return to the Earth, right up to completion of the flight program, if not otherwise provided for under international agreements of the Russian Federation.
5. Citizens of foreign countries undergoing training for space flight in the Russian Federation or participating in flight in a manned space object of the Russian Federation are obliged to adhere to the legislation of the Russian Federation if not otherwise provided for in the international agreements of the Russian Federation.

## **Article 21. Personnel of Surface and Other Space Infrastructure Facilities**

1. Specialists performing duties with respect to testing, storage and operation of space equipment, as well as other obligations in ensuring compliance to the technological soundness of functioning of surface and other space infrastructure facilities, are included among the personnel of surface and other space infrastructure facilities.
2. The functional duties of the personnel of surface and other space infrastructure facilities are determined by the organizations operating such facilities. The personnel of surface and other space infrastructure facilities are subject to certification that they comply to the stipulated personnel requirements.
3. The amount of wages and supplementary material compensation for personnel at surface and other space infrastructure facilities are determined by hiring contracts signed with the organizations using such facilities. The procedures for monetary compensation and material reward of personnel at surface and other space infrastructure facilities who are in the military service are determined by the appropriate legislation of the Russian Federation.
4. Individuals from among the personnel of surface and other space infrastructure facilities whose professions involve dangerous or harmful work conditions are provided additional compensation in accordance with the legislation of the Russian Federation and the conditions set forth in the corresponding contracts.
5. Individuals brought in for performing work on the elimination of the consequences of accidents and catastrophes occurring during the implementation of space activity are granted the compensations given to personnel of surface and other space infrastructure facilities.

## **Section V. Space Activity Safety**

### **Article 22. Ensuring Space Activity Safety**

1. Any space activity is carried out with adherence to the safety requirements established by legislation of the Russian Federation. The general leadership of work on ensuring the safety of flight activity is assigned to the Russian Space Agency and the Ministry of Defense of the Russian Federation. The task of taking space activity safety measures is assigned to the corresponding state services and also to organizations and citizens carrying out such activity. The bodies of state authority and administration of the Russian Federation and subjects of the Russian Federation, as well as organizations and citizens, are obliged to take all possible measures for ensuring space activity safety.
2. The Russian Space Agency and the Ministry of Defense of the Russian Federation at the request of interested organizations and citizens are obliged to supply information on the danger arising during the implementation of space activity. When a threat arises for the safety of the population and the environment, the Russian Space Agency immediately provides information on this to the appropriate bodies of state authority and administration, as well as to organizations and citizens.

### **Article 23. Investigation of Incidents Occurring During Implementation of Space Activity**

1. Incidents, including accidents and catastrophes, in the implementation of space activity, are subject to investigation, the procedures for which are defined by legislation of the Russian Federation.
2. The procedures for conducting investigation of incidents, including accidents and catastrophes, and validation of the results, can be appealed in court.



#### **Article 24. Search and Emergency Rescue Work, Elimination of Consequences of Incidents**

1. Search and emergency rescue work, as well as elimination of the consequences of incidents occurring during the implementation of space activity, are carried out by the appropriate state services with the participation of the bodies of state authority and administration of subjects of the Russian Federation, local self-administration bodies, as well as organizations and citizens.
2. Work on eliminating the consequences of incidents occurring during the implementation of space activity includes the restoration and reconstruction of industrial and other objects suffering as a result of incidents, necessary environmental protection measures and compensation for losses sustained by subjects of the Russian Federation, organizations, and citizens.
3. Search and emergency rescue work, as well as work on the elimination of the consequences of incidents occurring during the implementation of space activity in the territory of a foreign state, is carried out in coordination with competent bodies of that country at the expense of the organizations and citizens carrying out such activity, the resources of the Russian Space Fund, or the republic budget of the Russian Federation.

#### **Article 25. Insurance for Space Activity**

1. Organizations and citizens which operate space equipment or under whose orders space equipment is developed and used for scientific and economic purposes carry mandatory insurance in an amount prescribed by legislation of the Russian Federation. Mandatory insurance is provided in the case of loss of life or loss of health by cosmonauts, personnel of surface and other space infrastructure facilities, as well as property loss by third parties. Contributions for mandatory insurance constitute an item in the Russian Space Fund or other insurance organizations receiving a license for insuring space activity and are used in compensating for losses resulting from incidents occurring during the implementation of space activity on the basis of insurance contracts with organizations and citizens performing such activity.
2. Organizations and citizens engaged in space activity may carry voluntary insurance for space equipment and also the risks associated with such activity.
3. The insuring of personnel of organizations carrying out space activity is through these organizations in accordance with legislation of the Russian Federation.

### **Section VI. International Cooperation**

#### **Article 26. International Obligations in Space Activity Field**

1. The international agreements of the Russian Federation on matters related to space activity are subject to ratification by the Supreme Soviet of the Russian Federation.
2. If an international agreement ratified by the Supreme Soviet of the Russian Federation provides for rules different than those which are set forth in this Law and other legislative acts of the Russian Federation regulating space activity, the provisions of the international agreement apply.
3. The Russian Federation ensures compliance with the international obligations which it has assumed in the space activity field, including under the Agreement on the Principles of Activity of States in Exploring and Using Space, Including the Moon and Other Celestial Bodies.

4. The Russian Federation participates in the development of international cooperation in the space activity field, and also solution of problems in international law related to the exploration and use of space.

#### **Article 27. Juridical Rules for Foreign Organizations and Citizens**

1. Foreign organizations and citizens engaged in space activity under the jurisdiction of the Russian Federation are subject to the juridical rules established for the organizations and citizens of the Russian Federation to that degree to which such a regime is afforded by the corresponding state to the organizations and citizens of the Russian Federation.
2. The Russian Federation provides juridical protection for the technologies and commercial secrets of foreign organizations and citizens carrying out space activity under the jurisdiction of the Russian Federation in accordance with the legislation of the Russian Federation. Other necessary protection for the technologies and commercial secrets of foreign organizations and citizens carrying out space activity under the jurisdiction of the Russian Federation is ensured on a reciprocal basis.
3. Foreign organizations and citizens carrying out space activity under the jurisdiction of the Russian Federation carry insurance for space equipment, and also for the risks associated with space activity under the provisions set forth in this Law.

#### **Article 28. Juridical Regulation of International Cooperation**

1. Organizations and citizens of the Russian Federation participating in the implementation of international projects in the space activity field conclude agreements with foreign organizations and citizens in accordance with the legislation of the Russian Federation, unless otherwise stipulated in these agreements.
2. In the case of conflict between the legislative norms of the Russian Federation and the legislation of foreign states applicable to space activity with the participation of the organizations and citizens of the Russian Federation the legislation of the Russian Federation applies if not provided for otherwise by international agreements of the Russian Federation.

### **Section VII. Responsibility**

#### **Article 29. Responsibility of Officials, Organizations and Citizens**

State organizations and their officials, as well as citizens guilty of violation of this Law and other legislative acts regulating space activity, bear responsibility in accordance with legislation of the Russian Federation.

#### **Article 30. Responsibility for Losses**

1. The Russian Federation guarantees full compensation for the direct losses sustained as a result of incidents occurring during the implementation of space activity in accordance with the legislation of the Russian Federation.
2. The compensation for losses sustained as a result of an incident occurring during the implementation of space activity is paid by the organizations and citizens operating space equipment. If such loss is a result of the errors allowed in developing and using space equipment, the obligation for compensating for the losses is imposed partially or fully on the corresponding organizations and the corresponding citizens.

3. A responsibility for the loss caused by a space object of the Russian Federation in the territory of the Russian Federation or beyond the jurisdictional limits of any state, other than in space, arises independently of the fault of the party responsible for the loss. If at any place, in addition to at the Earth's surface, a space object of the Russian Federation or the property aboard such an object causes a loss to another space object, a responsibility of organizations and citizens arises when they bear fault and is commensurable to their fault. If the responsibility for a loss caused by a space object of the Russian Federation is borne by several organizations and citizens, a claim by the damaged party for the payment of compensation for losses can be made to all such organizations and citizens or any of them. In the latter case the organization or citizen compensating for the loss has the right to a counteraction against correspondents whose responsibility is distributed commensurably to the degree of their fault, but if the degree of fault cannot be determined it is distributed evenly.

The responsibility of organizations and citizens participating in the development and use of space equipment for compensating for the losses sustained as a result of incidents occurring during the implementation of space activity is limited to the amount of the insured sum or the insurance indemnification provided for in the contracts for the insurance for space equipment and the risks associated with space activity. If the insured sum or insurance indemnification are inadequate for compensating for the losses sustained as a result of incidents occurring during the implementation of space activity, the search for recovery can be directed against the property of the corresponding organizations and citizens in the manner prescribed by legislation of the Russian Federation.

**7.4 Decree 1282 of the Council of Ministers of the Russian Federation: "State Support and Backing for Space Activity in the Russian Federation" (adopted 11 December 1993)**

For the preservation and priority development of Russia's space potential in the interests of the economy, science, and technology, and for support of the country's defense and security, the Council of Ministers - Government of the Russian Federation resolves:

1. To approve the appended Federal Space Program for the Period up to the Year 2000.

Considering the particular importance of the Federal Space Program of Russia, to establish that the operations specified by this program shall be provided with material and technical resources according to the procedure customary for a state defense order. That, when putting together the draft republican budget of the Russian Federation for the next year, the Russian Federation Ministry of Economics and the Russian Federation Ministry of Finance shall provide for the funding of the said program via the Russian Space Agency on a separate line for research and development, capital construction (state investments), purchases of batch-produced space equipment and operational expenditure on the maintenance of groundbased facilities of the space infrastructure, this expenditure being referred to protected items of the budget.

To authorize the Russian Space Agency to carry out the Federal Space Program of Russia; to conclude long-term contracts (agreements) with those working on the building of research and national economic space complexes; to purchase all the batch-produced space complexes and make interim payments for the work on these complexes to the extent of 30% of their cost.

2. For the continued development and sophistication of the groundbased facilities of the space infrastructure of Russia:

that the Russian Federation Ministry of Defense, the Russian Federation State Committee for the Defense Sectors of Industry, the Russian Space Agency, the Russian Federation Ministry of Economics, and the Russian Federation Ministry of Finance shall, within a month's time, draw up and present to the Council of Ministers - Government of the Russian Federation proposals pertaining to development of the Plesetsk cosmodrome and the building of a cosmodrome in Russia's Far East region;

that the Russian Federation Ministry of Defense, the Russian Space Agency, the Russian Federation State Committee for the Defense Sectors of Industry, and the Russian Federation of Finance shall draw up and present to the Russian Federation Ministry of Economics proposals pertaining to the assimilation by enterprises of the Russian Federation of the production of materials, elements and components, and rocket and space technology formerly produced by enterprises of CIS participants, with the requisite calculations and feasibility studies;

that the Russian Federation Ministry of Defense (military space forces) and the Russian Space Agency shall conclude contracts and effect mutual settlements in respect of them directly with the enterprises of the CIS participants taking part in cooperation in the building of rocket and space equipment of the Russian Federation.

3. That the Russian Federation Ministry of Finance shall for the funding of operations pertaining to the Federal Space Program of Russia:

appropriate for the Russian Space Agency in 1993 some R126 billion for research and development, R7.8 billion for operational expenditure on the maintenance of facilities of the Baikonur cosmodrome, R21 billion for purchases of batch-produced space equipment and R10 billion for capital construction (state investments);

earmark in 1994 for the Russian Space Agency appropriations of R167 billion for research and development, R16 billion for operational expenditure on the maintenance of the facilities of the Baikonur cosmodrome, R81.8 billion for purchases of batch-produced space equipment, and R10 billion for capital construction (state investments) (in July 1993 prices).

4. To authorize the Russian Federation Ministry of Defense and the Russian Space Agency to effect phased payment for the batch-produced space equipment and to pay for the manufactured components.
5. That, when administering the republican budget of the Russian Federation, the Russian Federation Ministry of Finance shall allocate annually in the first quarter appropriations for interim payments for work pertaining to the Federal Space Program of Russia in the amount of not less than 30% of the annual funding of research and development, operational expenditure on maintenance of facilities of the Baikonur cosmodrome and the purchase of batch-produced space equipment and capital construction, and shall index the appropriations for these types of work in accordance with the change in the price level.
6. That the Russian Federation Ministry of Economics and the Russian Federation Ministry of Finance shall make available in the 1994-1996 period soft conversion loans to support the production of space equipment for the Central Specialized Design Bureau, the Applied Mechanics Research-Production Association, the S. A. Lavochkin Research-Production Association, the Precision Instruments Research-Production Association, the M. V. Khrunichev State Space Research-Production Center, the Samara Progress Plant, the Samara M. V. Frunze Machine-Building Association, the Permskiy Motory stock company, the Voronezh Machine Plant, the Arsenal Machine-Building Plant, the Academician S. P. Korolev Energiya Research-Production Association, the Academician V. P. Glushko Energomash Research-Production Association, the Admiralteyskiy Verfi state-owned enterprise, the Chemical Machine-Building Scientific Research Institute, the Russian Scientific Institute of Instrument Making for Space, and the Kazan Tasma Production Association if they have conversion programs.
7. That the Russian Federation State Committee for the Defense Sectors of Industry and the Russian Space Agency shall, in conjunction with the Russian Federation State Committee for the Management of State Property, present to the Council of Ministers - Government of the Russian Federation within a month's time proposals pertaining to the structural reorganization of the rocket and space sector of Russia's industry.
8. For the work on the building and production of space equipment, to establish a planned profitability of up to 35% of the total costs of the work in the manufacture of space equipment and of up to 40% of the original work in the development of space equipment.

To extend to the work on research and national economic space equipment the Statute on a Lump-Sum Bonus for the Workforce of Enterprises and Organizations for the Creation of New Models of Arms and Military Equipment and the Performance of Most Important Scientific Research approved by Decree No. 558 of the Council of Ministers - Government of the Russian Federation of 16 June 1993.

9. From 1st January 1994, to introduce for employees of enterprises, organizations, and institutions, regardless of forms of ownership and of ministries and departments assigned to the Baikonur cosmodrome, the privileges accorded by Supplement 1 for special work for the length of their stay at the cosmodrome.
10. That the Russian Federation Ministry of Finance, following a recommendation of the Russian Space Agency, shall allocate to the enterprises foreign currency loans for the fulfillment of the contracts (agreements) that have been concluded in the sphere of space within the framework of international arrangements.

11. That the Russian Space Agency, the Russian Federation State Committee for the Defense Sectors of Industry and the Russian Federation Ministry of Defense shall, in conjunction with the Russian Federation Ministry of Science and Technical Policy and the Russian Federation Ministry of Economics, present within three month's time to the Council of Ministers - Government of the Russian Federation proposals pertaining to the creation, on the basis of enterprises and organizations of the space industry, of federal space centers and a draft statute on a federal space center with a view to the concentration of orders for space equipment at a minimum number of enterprises and assurance of their state support.
12. That the Russian Federation Ministry of Defense shall within a month's time prepare and present, according to the established procedure, a Council of Ministers - Government of the Russian Federation draft decree on measures to ensure the social protection of servicemen of the Russian Federation Ministry of Defense serving at Baikonur cosmodrome and their families.
13. To authorize the Russian Space Agency to hold a general director's reserve for the funding of unforeseen operations in the amount of up to two per cent of the annual funding of work on the Federal Space Program of Russia.
14. To extend to employees of the Russian Space Agency the terms of remuneration and material-consumer and medical services, and also the privileges and benefits in effect for employees of ministries and state committees of the Russian Federation.
15. To increase the maximum numbers of employees of the central staff of the Russian Space Agency by 40 with a corresponding increase in the wage fund. That the Russian Federation of Finance shall submit to the Council of Ministers - Government of the Russian Federation proposals concerning a supplementary wage fund for employees of the central staff of the Russian Space Agency.
16. To authorize additionally for the Russian Space Agency the office of deputy director-general.
17. To approve the measures to support the activity of the Russian Space Agency according to Supplement 2.

**Supplement 1. Privileges for Employees of Enterprises, Organizations and Institutions and Ministries and Departments of the Russian Federation Assigned to the Baikonur Cosmodrome for Special Work**

1. For employees of enterprises, organizations, and institutions, regardless of forms of ownership, and of ministries and departments assigned to the Baikonur cosmodrome for preparing and conducting tests, completing and maintaining space equipment, performing manufacturer's warranty (technical) service and carrying out construction, installation, and startup-debugging work to ensure the realization of space programs (hereinafter called "the employees"), the following are established for the time of their stay at the cosmodrome:
  - a compensation payment to the amount of 25 times the minimum wage established by legislation on a monthly basis;
  - a per diem allowance payment (including for servicemen other than compulsory service personnel) at the current rates with an increase by a factor of 1.5;
  - annual supplementary paid leave of one work day per month of time spent at the cosmodrome, but not more than seven work days (as in an environmental precrisis-condition zone).

2. For the employees and their families the following supplementary privileges pertaining to the protection of mother and child shall be introduced:

prenatal leave spent on the territory of the Russian Federation with free return travel to the leave point;

compensation of 50% of the cost of food on the dispensary register obtained for children;

annual accommodation free of charge for children up to 16 years of age who have lived at the cosmodrome for more than a year in specialized children's institutions of a medical or sanitarium type and other health and fitness establishments on the territory of the Russian Federation with free travel there and back.

3. The Russian Space Agency and the Russian Federation State Committee for the Defense Sectors of Industry shall finance within the limits of the appropriations allocated them the construction of housing for the employees.
4. Payments and compensation to the employees and their families shall be made by the organizations, enterprises, and institutions and ministries and departments of the Russian Federation assigning their employees to the Baikonur cosmodrome. The expenditure on the payments and sums of compensation shall be included in the cost of the product and the estimated expenditure on the maintenance of publicly funded organizations and ministries and departments of the Russian Federation.

#### **Supplement 2. Measures to Support the Activity of the Russian Space Agency.**

1. To authorize the Russian Space Agency to:

to form off-budget funds, including foreign currency funds, from the voluntary contributions of enterprises and organizations and also from other sources, including allocations in the amount of 1.5% from the prime costs of jobs (services) on the building of research and national economic rocket and space equipment, and to use part of the said resources to support unforeseen work in the interests of the Federal Space Program of Russia and foreign economic activity and also for the development of a system of training and retraining of specialists and the solution of individual questions of social-consumer and medical services and the social protection of employees of the central staff of the Russian Space Agency and enterprises under its jurisdiction;

in accordance with international treaties and agreements that have been concluded, to make contributions from the off-budget funds to enterprises and other legal entities founded with its participation and to purchase shares of stock and securities contributing to the accomplishment of the missions entrusted to the agency.

2. To allocate to the Russian Space Agency on an operational management basis an administrative building at 42 (structures 1 and 2) ulitza Shchepkina, Moscow with engineering facilities, including means of communication, and inventory and other state property providing for the normal functioning of the staff of the agency and the operation of the said administrative building. That the Russian Federation State Committee for the Management of State Property shall exclude from the capital fund of the Eksikom Stock Company state assets that are not due to be contributed to the capital fund and also the engineering facilities, means of communication, inventory, and other state assets providing for the normal operation of the said administrative building and contributed earlier to the capital fund of the Eksikom Stock Company.
3. To include the Russian Space Agency on the list of properties subject to state protection approved by Russian Federation Government Decree No. 587 of 14th August 1992, "Questions of Private Detective and Security Activity". To authorize the formation under the auspices of the Russian Space Agency of a detachment of Category I militarized security.

4. By 1st January 1994, to establish an extra monthly payment in the amount of up to 20% of salary for employees of the Russian Space Agency working directly with secret documents.



**7.5 Memorandum of Understanding of the Heads of Government of the Russian Federation and the Republic of Kazakhstan, "On Mutual Understanding on Maintaining the Operational Use of the Baikonur Cosmodrome " (Signed 26 December 1993)**

The Heads of Government of the Russian Federation and the Republic of Kazakhstan held a special meeting devoted to a comprehensive exchange of views on ways and means of ensuring the proper functioning of the Baikonur space center.

The Heads of Government of the Russian Federation and the Republic of Kazakhstan, building on earlier understandings, consider it necessary to draw up a draft agreement for the purpose of ensuring the stable functioning of the Baikonur space center and its efficient exploitation in the interests of the Russian Federation, the Republic of Kazakhstan, and other states.

The Heads of Government agreed that the Russian Federation and the Republic of Kazakhstan would, in matters concerning the Baikonur space center, be guided by the following basic principles:

1. The Russian Federation and the Republic of Kazakhstan shall pursue coordinated policies with a view to expanding cooperation in the exploration and use of space, the further development of the Baikonur space center in support of national and international space programs, and also of commercial space projects.

The parties shall, via the appropriate organizations, assist in the execution by the authorities and legal persons of the two countries of cooperative projects involving use of the Baikonur space center.

2. The Baikonur space center must be preserved as a resource of great importance for the civil and military space programs of the Russian Federation and the commonwealth as a whole and of international cooperative programs.

For use of the Baikonur space center for the above purposes, the Russian Federation shall pay rental to the Republic of Kazakhstan. The specific terms of such rental shall take account of other matters relevant to Russian-Kazakh relations.

The Baikonur space center and the town of Leninsk shall be exploited by the Government of the Russian Federation or the state authorities empowered by it to do so. In this connection, the question of the inclusion of the town of Leninsk in the resources to be rented shall be considered separately with due regard for the laws of the Republic of Kazakhstan.

3. The rights and obligations acquired by the Directorate of Space Resources of the Armed Forces of the CIS by virtue of the Agreement of 25 May 1992 between the Russian Federation and the Republic of Kazakhstan concerning use of the Baikonur space center shall be entirely vested in and performed by the Military Space Forces of the Russian Federation.

In this regard, the parties recognize that the Russian military units at the Baikonur space center are located on the territory of the Republic of Kazakhstan on a temporary basis and that their activities are governed by the laws of the Republic of Kazakhstan and of the Russian Federation.

The parties agree that matters concerning security, the preservation of law and order, jurisdiction, and also concerning social and legal guarantees in respect of persons forming part of the Russian military units at the Baikonur space center, members of their families, civilian personnel at the space center, and persons on mission, will be covered by the agreement concerning the Baikonur space center in accordance with the laws of the Russian Federation and of the Republic of Kazakhstan.

4. The Russian Federation and the Republic of Kazakhstan are proceeding on the assumption that the ownership of objects, buildings and installations, hardware, armaments, equipment, and other assets produced, acquired, or provided after 31 August 1991 belong to the party which funded them.

For the purpose of drawing up the above-mentioned agreement and of resolving problems that might arise with regard to the Baikonur space center, the Heads of Government have set up an intergovernmental commission chaired by the Deputy Prime Ministers of the Governments of the Russian Federation and of the Republic of Kazakhstan. The commission has been instructed to submit within two months, a draft Agreement and a draft accord on rental of the space center, taking into account the main provisions of the present Memorandum.

**7.6 Russian Government Directive No. 624-r (signed 3 May 1994)**

1. The Energiya Scientific Production Association named after Academician S. P. Korolev shall be authorized to create in accordance with prescribed procedure, jointly with foreign participants, an enterprise to develop a sea-based space rocket for launching various space devices.
2. The Energiya Scientific Production Association named after Academician S. P. Korolev shall be given responsibility for coordinating the work of Russian enterprises and cooperating with Ukrainian enterprises in the creation of the above space rocket complex.

**7.7 Russian Federation Government Decree 996: "On Measures To Ensure Fulfillment of the 28 March 1994 Agreement Between the Russian Federation and the Republic of Kazakhstan on the Basic Principles and Conditions Governing the Use of the Baikonur Space Center" (signed 29 August 1994)**

The Russian Federation Government decrees that:

1. The Russian Federation Defense Ministry and the Russian Space Agency, in conjunction with interested ministries and departments and in accordance with Article 6 of the 28 March 1994 Agreement between the Russian Federation and the Republic of Kazakhstan on the Basic Principles and Conditions Governing the Use of the Baikonur Space Center, shall submit a draft agreement on leasing of the Baikonur complex to the Russian Federation Government within one month.
2. The Russian Federation Defense Ministry shall within one month implement measures in conjunction with the Kazakhstani side to transfer facilities at the Baikonur Space Center used to implement the Russian Federal Space Program, in accordance with the appendix, to the use and possession of the Russian Space Agency. The transfer of facilities at the Baikonur Space Center to the use and possession of the Russian Space Agency shall take place under acts ratified by the Russian Federation Defense Ministry and the general director of the Russian Space Agency, as well as by the leaders of Republic of Kazakhstan ministries and departments in conjunction with the Kazakhstani side.
3. The Russian Federation Finance Ministry shall allocate \$115 million in 1994 to pay for the leasing of the Baikonur complex and also for the upkeep of the Baikonur complex in the amounts envisaged by the federal budget for 1994, including:
  - the sum of 191.2 billion rubles (R) to the Russian Federation Defense Ministry for the Military Space Forces;
  - R179.2 billion to the Russian Space Agency, including R53.8 billion for operational expenditure, R17.6 billion for the purchase of series-produced space equipment, R15.8 billion for capital construction, and R91 billion for the upkeep of the city of Leninsk.
4. The Russian Federation Defense Ministry shall continue under the established system and on a contract basis to supply facilities at the Baikonur Space Center with electricity, water, heat, rocket fuel, fuels and lubricants, and other materials, shall organize rail shipments of workers and freight within the space center precincts, and shall provide aviation services at the Krayniy airfield (landing clearance, servicing, refueling, security, and dispatch of air transport enterprises' assets), metrological, meteorological, medical, and other services.
5. The Russian Federation Defense Ministry shall be authorized to recruit civilian specialists to be paid under the procedure laid down by Russian Federation legislation in order to operate power, heat, and water supply systems, as well as sewage and communications systems at general space center installations.
6. Russian Federation enterprises and organizations shall be authorized to use the funds allocated to them to ensure the upkeep, operation, capital construction, modernization, overhaul, and day-to-day repair of facilities at the Baikonur Space Center and to accept citizens from the CIS states for jobs ensuring the running of these facilities. Reports on the utilization of the aforesaid assets shall be delivered under the procedure laid down for facilities included on the balance sheets of these enterprises and organizations on Russian Federation territory.

7. The Russian Federation Ministry of Education shall:

- ensure the organization of the education of school children at educational establishments in the city of Leninsk under Russian Federation plans and programs;
- coordinate with the Republic of Kazakhstan Ministry of Education the questions of the education of Kazakhs under national programs, and of the recognition on Republic of Kazakhstan territory of the educational documents issued in educational establishments in the city of Leninsk.

8. The Russian Federation State Committee for Higher Education shall examine the question of the possibility of training the specialists required by the Baikonur Space Center at a branch of the Moscow Aviation Institute, altering training programs if necessary.
9. The Russian Federation Foreign Ministry, the Russian Space Agency, the Russian Federation Defense Ministry, the Russian Federation Ministry of Internal Affairs, the Russian Federation Federal Counterintelligence Service, the Russian Federation Ministry of Justice, and the Russian Federation Ministry of Social Protection of the Population shall elaborate within three months in conjunction with the Kazakhstani side the possibility of creating in the city of Leninsk a closed administrative-territorial formation in line with the Russian Federation law "On Closed Administrative-Territorial Formations" and shall draw up within one month proposals on the candidate to be appointed head of the Leninsk City Administration.
10. The Russian Federation Defense Ministry in conjunction with the Russian Space Agency and by agreement with the Kazakhstani side shall set up a coordinating organ at the Baikonur Space Center headed by the chief of the space center, and shall submit the relevant proposals to the Russian Federation Government within two months.
11. With a view to organizing the work to operate groundbased space infrastructure facilities, the Russian Space Agency shall set up a corresponding organ of 75 people under the agency. This organ shall be funded from monies earned for work and service performed.
12. The Russian Space Agency and the Russian Federation Defense Ministry in conjunction with the Russian Federation Ministry of Fuel and Energy, the Russian Federation Ministry of Railways, the Russian Federation Ministry of Transport, the Russian Federation Ministry of Communications, the Russian Federation Ministry of Education, the Russian Federation Ministry of Culture, the Russian Federation Committee for Water Resources, and other interested ministries and departments shall prepare and submit to the Russian Federation Government by 15 November 1994 proposals on the organization starting in 1995 of funding, material and technical support for and the operation by these ministries and departments of the general space center facilities at the Baikonur complex, fully resolving the aforesaid tasks as of 1997.

**7.8 Russian Federation Federal Law No. 28-F3: "On the Ratification of the Agreement Between the Russian Federation and the Republic of Kazakhstan on the Basic Principles and Conditions of the Utilization of the Baikonur Cosmodrome" (signed 24 October 1994)**

**Article 1.**

The Agreement Between the Russian Federation and the Republic of Kazakhstan on the Basic Principles and Conditions of the Utilization of the Baikonur Cosmodrome, signed in the city of Moscow 28 March 1994, is ratified.

**Article 2.**

The Russian Federation Government is to submit the treaty on leasing the Baikonur complex between the Russian Federation and Republic of Kazakhstan Governments to the State Duma for ratification after it has been concluded in accordance with Article 6 of the agreement, together with the 20-year federal program to develop a groundbased infrastructure for space assets.

**Article 3.**

Following ratification of the treaty on leasing the Baikonur complex, the Russian Federation Government is to adopt a decision on the opening of financing for the payment of rent for the Baikonur complex and for reimbursing the Republic of Kazakhstan's property losses and expenditure on maintaining and operating the Baikonur complex in 1992-1993.

**7.9 Russian Presidential Edict: "On the Organization of the Further Utilization of the Baikonur Cosmodrome in the Interests of the Russian Federation's Space Activity" (signed 24 October 1994)**

With a view to efficiently utilizing the Baikonur Cosmodrome for the implementation of Russia's space programs and in connection with the signing of the Agreement on the Basic Principles and Conditions of the Utilization of the Baikonur Cosmodrome between the Russian Federation and the Republic of Kazakhstan, I decree that:

1. The Russian Federation Government is to organize the takeover of the Baikonur complex from the government of Kazakhstan and ensure its proper functioning . Proposals for candidacy for the post of head of Leninsk City Administration are to be prepared within one month.

The following provisions are to be made during the formation and amplification of the federal budget:

- the allocation of appropriations to pay for the lease of the Baikonur Cosmodrome and the upkeep of the city of Leninsk;
  - the allocation of appropriations to the Russian Space Agency and the Russian Federation Ministry of Defense for expenditure by the Military Space Forces on operational costs and purchases of series-produced equipment for the utilization, maintenance, upgrading, and tooling of the Baikonur Cosmodrome's facilities and the upkeep of servicemen;
  - the allocation of the necessary volume of capital investment, including for the construction of housing in the Russian Federation for persons discharged from military service after serving with the Russian Federation Armed Forces on the territory of the Baikonur Cosmodrome, and also for employees of enterprises and organizations working in the Baikonur complex on a permanent basis.
2. It is prescribed that the financial, material, and technical support for, and the utilization of, the Baikonur complex facilities used for the implementation of Russian military space programs are to be carried out by the Russian Federation Ministry of Defense (Military Space Forces), and that these functions as regards the implementation of Russia's federal space program are to be carried out by the Russian Space Agency under contracts with industrial enterprises and organizations and the cosmodrome's military units. The financial, material, and technical support of facilities connected with ensuring the proper functioning of the Baikonur complex is to be shared proportionately between the Russian Federation Ministry of Defense (Military Space Forces) and the Russian Space Agency.
  3. A special military contingent numbering 16,000 men, including 3,800 officers, and not forming part of the numerical strength of the Russian Federation Armed Forces, is to be maintained from 1 January 1995 through 1 January 1997, from funds allocated to the Russian Space Agency from the federal budget, as part of the Military Space Forces for the implementation of space programs for scientific and national-economic purposes and international cooperation, and also for the utilization of facilities connected with ensuring the proper functioning of the Baikonur complex. The Russian Federation of Defense is to ensure the manning levels of the aforementioned military contingent and provide it with all types of allowance.
  4. The Russian Federation Ministry of Defense (Military Space Forces) are charged with the overall coordination of work carried out at the Baikonur Cosmodrome.
  5. This edict comes into force on the day it is signed.





## **SECTION 8. 1993-1994 EURASIAN SPACE LAUNCHES**

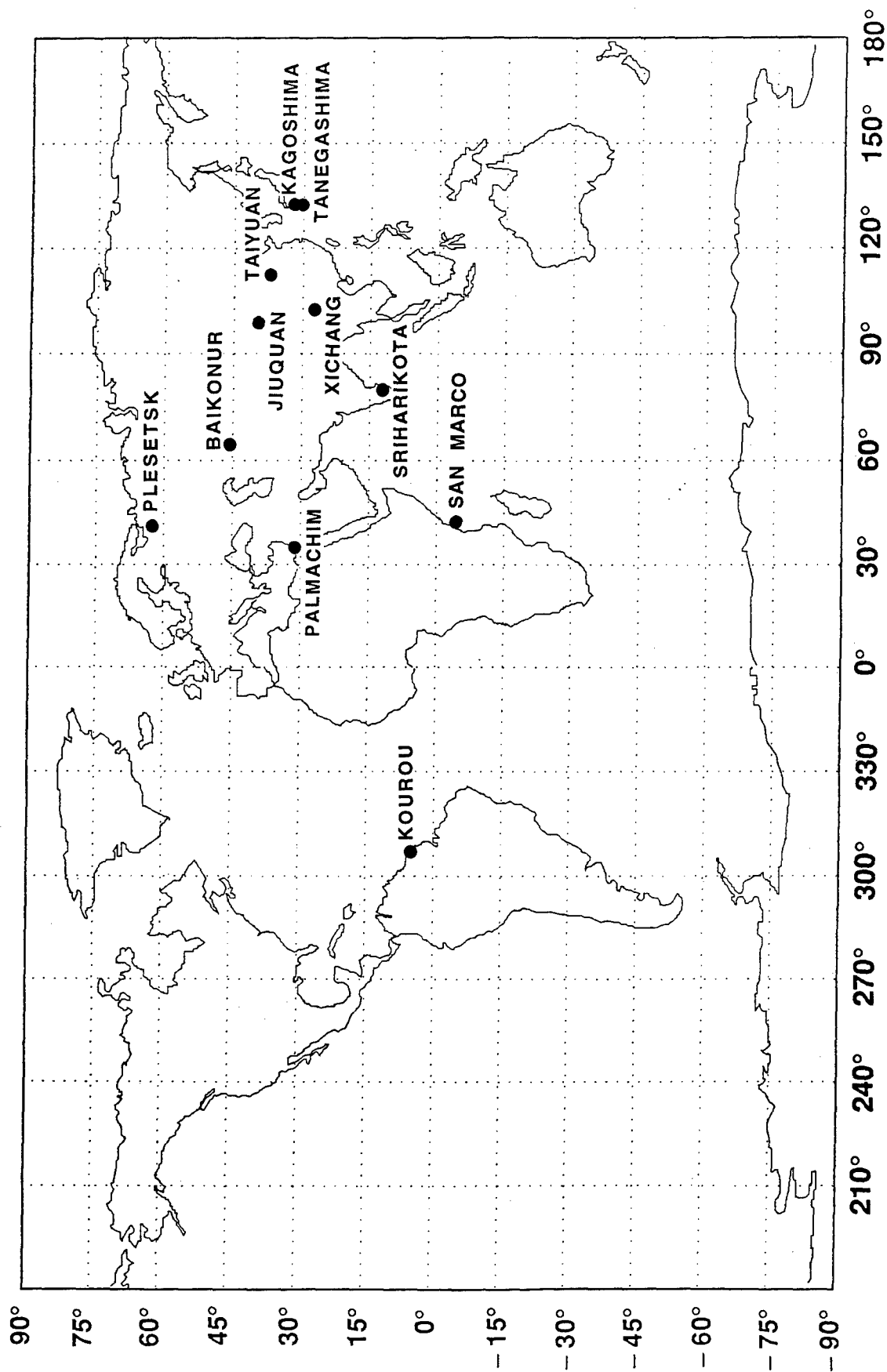


TABLE 8.1 CIS LAUNCH HISTORY, 1993

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
12.47 JAN	KOSMOS 2230	22307	1993-01A	KOSMOS-3M	PLESETSK	973	1007	82.94	104.90	NAVIGATION	REPLACED KOSMOS 2181
13.08 JAN	MOLNIYA 1-85	22309	1993-02A	MOLNIYA-M	PLESETSK	606	39746	62.85	717.72	COMMUNICATIONS	REPLACED MOL 1-78; ON STATION 19 JAN
19.62 JAN	KOSMOS 2231	22317	1993-04A	SOYUZU	PLESETSK	165	345	67.13	89.61	PHOTO RECON	4TH GENERATION; RETURNED 25 MAR
24.25 JAN	SOYUZ TM-16	22319	1993-05A	SOYUZU2	BAIKONUR	392	394	51.62	92.41	MANNED	DOCKED AT MIR 26 JAN; UNDOCKED 22 JUL
26.66 JAN	KOSMOS 2232	22321	1993-06A	MOLNIYA-M	PLESETSK	598	39770	62.77	718.05	EARLY WARNING	REPLACED KOSMOS 2001; ON STATION 30 JAN
4.00 FEB	BANNER	22449	1986-17GZ		MIR	390	393	51.62	92.39	SCIENTIFIC	ATTACHED TO PROGRESS M-15 AND THEN RELEASED; SOLAR SAIL/REFLECTOR EXP.
9.12 FEB	KOSMOS 2233	22487	1993-08A	KOSMOS-3M	PLESETSK	954	1009	82.94	104.72	NAVIGATION	REPLACED KOSMOS 2142
17.84 FEB	KOSMOS 2234 KOSMOS 2235 KOSMOS 2236	22512 22513 22514	1993-10A 1993-10B 1993-10C	PROTON-K (4)	BAIKONUR	19107 19112 19096	19153 19149 19165	64.83 64.83 64.84	675.74 675.73 675.75	NAVIGATION NAVIGATION NAVIGATION	REPLACED KOSMOS 2177 REPLACED KOSMOS 1987 FILLED VACANT 8TH ORBITAL PLANE POSITION
21.77 FEB	PROGRESS M-16	22530	1993-12A	SOYUZU2	BAIKONUR	388	392	51.62	92.36	MIR RESUPPLY	DOCKED 23 FEB; UNDOCKED 27 MAR
25.10 MAR	RADUGA 29	22557	1993-13A	PROTON-K (4)	BAIKONUR	35772	35807	1.46	1436.26	COMMUNICATIONS	POSITIONED AT 12 E
25.55 MAR	START 1 (EKA 1)	22561	1993-14A	START-1	PLESETSK	683	970	75.76	101.44	TEST	MAIDEN FLIGHT OF START 1 BASED ON SS-25
26.10 MAR	KOSMOS 2237	22565	1993-16A	ZENIT-2	BAIKONUR	849	853	71.02	101.95	ELINT	TSELINA 2 CLASS; REPLACED KOSMOS 1980
30.50 MAR	KOSMOS 2238	22585	1993-18A	TSYKLON-2	BAIKONUR	404	417	65.03	92.77	EO RSAT	REPLACED KOSMOS 2122 WHICH DECAYED ON 28 MAR
31.15 MAR	PROGRESS M-17	22588	1993-19A	SOYUZU2	BAIKONUR	394	395	51.62	92.44	MIR RESUPPLY	DOCKED 2 APR; UNDOCKED 11 AUG
1.79 APR	KOSMOS 2239	22590	1993-20A	KOSMOS-3M	PLESETSK	967	999	82.93	104.75	NAVIGATION	REPLACED KOSMOS 2173
2.60 APR	KOSMOS 2240	22592	1993-21A	SOYUZU	PLESETSK	190	322	62.85	89.62	PHOTO RECON	4TH GENERATION; RETURNED 7 JUN

TABLE 8.1 CIS LAUNCH HISTORY, 1993

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
6.80 APR	KOSMOS 2241	22594	1993-22A	MOLNIYA-M	PLESETSK	641	39771	62.88	718.95	EARLY WARNING	REPLACED KOSMOS 1974; ON STATION 10 APR
16.33 APR	KOSMOS 2242	22626	1993-24A	TSYKLON-3	PLESETSK	634	668	82.53	97.74	ELINT	NEW ORBITAL PLANE
21.02 APR	MOLNIYA 3-44	22633	1993-25A	MOLNIYA-M	PLESETSK	623	39739	62.85	717.92	COMMUNICATIONS	REPLACED MOL 3-41; ON STATION 26 APR
27.44 APR	KOSMOS 2243	22641	1993-28A	SOYUZ-U	BAIKONUR	190	238	70.35	88.78	PHOTO RECON	4TH GENERATION; BREAKUP OCCURRED AT ORBITAL INSERTION; NEVER OPERATIONAL
28.15 APR	KOSMOS 2244	22643	1993-29A	TSYKLON-2	BAIKONUR	404	417	65.03	92.78	EORSAT	PHASED WITH KOSMOS 2238
11.62 MAY	KOSMOS 2245 KOSMOS 2246 KOSMOS 2247 KOSMOS 2248 KOSMOS 2249 KOSMOS 2250 KOSMOS 2251	22646 22647 22648 22649 22650 22651	1993-30A 1993-30B 1993-30C 1993-30D 1993-30E 1993-30F	TSYKLON-3	PLESETSK	1397 1400 1403 1401 1404 1404	1418 1418 1418 1418 1418 1418	82.58 82.58 82.58 82.58 82.58 82.58	113.94 113.98 114.02 113.99 114.02 114.02	COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS	COPLANAR WITH KOSMOS 2211-2216
21.39 MAY	RESURS-F 17	22663	1993-33A	SOYUZ-U	PLESETSK	230	237	82.57	89.17	PHOTO RECON	3RD GENERATION; EARTH RESOURCES; F2 TYPE; RETURNED 20 JUN
22.28 MAY	PROGRESS M-18	22666	1993-34A	SOYUZ-U2	BAIKONUR	390	391	51.62	92.36	MIR RESUPPLY	DOCKED 24 MAY; UNDOCKED 3 JUL
26.14 MAY	MOLNIYA 1-86	22671	1993-35A	MOLNIYA-M	PLESETSK	440	39907	62.81	717.63	COMMUNICATIONS	REPLACED MOL 1-81; ON STATION 12 JUN
27.06 MAY	GORIZONT - - -	NONE	NONE	PROTON-K (4)	BAIKONUR	***	***	***	***	COMMUNICATIONS	FAILED TO REACH ORBIT DUE TO 2ND STAGE AND 3RD STAGE MALFUNCTIONS
16.18 JUN	KOSMOS 2251	22675	1993-36A	KOSMOS-3M	PLESETSK	781	806	74.04	100.74	COMMUNICATIONS	REPLACED KOSMOS 2112
24.18 JUN	KOSMOS 2252 KOSMOS 2253 KOSMOS 2254 KOSMOS 2255 KOSMOS 2256 KOSMOS 2257	22687 22688 22689 22690 22691 22692	1993-38A 1993-38B 1993-38C 1993-38D 1993-38E 1993-38F	TSYKLON-3	PLESETSK	1405 1410 1394 1406 1402 1409	1416 1426 1414 1415 1414 1420	82.58 82.59 82.58 82.59 82.58 82.58	114.01 114.17 113.87 114.01 113.96 114.10	COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS	COPLANAR WITH KOSMOS 2197-2202
25.35 JUN	RESURS-F 18	22696	1993-40A	SOYUZ-U	PLESETSK	223	243	82.59	89.16	PHOTO RECON	3RD GENERATION; EARTH RESOURCES; F1 TYPE; RETURNED 12 JUL

TABLE 8.1 CIS LAUNCH HISTORY, 1993

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
1.61 JUL	SOYUZ TM-17	22704	1993-43A	SOYUZ-U2	BAIKONUR	388	395	51.62	92.39	MAINED	DOCKED AT MIR 3 JUL; UNDOCKED 14 JAN 94
7.30 JUL	KOSMOS 2258	22709	1993-44A	TSYKLON-2	BAIKONUR	403	418	65.04	*92.78	EORSAT	PHASED WITH KOSMOS 2238 AND 2244
14.69 JUL	KOSMOS 2259	22716	1993-45A	SOYUZ-U	PLESETSK	179	358	67.13	89.87	PHOTO RECON	4TH GENERATION; RETURNED 25 JUL
22.36 JUL	KOSMOS 2260	22721	1993-47A	SOYUZ-U	PLESETSK	241	297	82.29	89.89	PHOTO RECON	3RD GENERATION; EARTH RESOURCES RESURS-T TYPE; RETURNED 5 AUG
4.04 AUG	MOLNIYA 3-45	22719	1993-49A	MOLNIYA-M	PLESETSK	412	39928	62.82	717.48	COMMUNICATIONS	REPLACED MOL 3-37; ON STATION 9 AUG
10.62 AUG	KOSMOS 2261	22741	1993-51A	MOLNIYA-M	PLESETSK	581	39758	62.89	717.47	EARLY WARNING	REPLACED KOSMOS 2050; ON STATION 13 AUG
10.83 AUG	PROGRESS M-19	22745	1993-52A	SOYUZ-U	BAIKONUR	387	393	51.62	92.35	MIR RESUPPLY	DOCKED 12 AUG; UNDOCKED 12 OCT
24.45 AUG	RESURS-F 19	22777	1993-53A	SOYUZ-U	PLESETSK	224	234	82.59	89.08	PHOTO RECON	3RD GENERATION; EARTH RESOURCES F1 TYPE; RETURNED 10 SEP
31.19 AUG	METEOR 2-21 TEMISAT	22782 22783	1993-55A 1993-55B	TSYKLON-3	PLESETSK	938 937	969 969	82.55 82.50	104.13 104.11	METEOROLOGY COMMERCIAL	ITALIAN PIGGY-BACK PAYLOAD
7.56 SEP	KOSMOS 2262	22789	1993-57A	SOYUZ-U2	BAIKONUR	207	325	64.89	89.83	PHOTO RECON	6TH GENERATION; DESTROYED IN ORBIT 18 DEC
16.32 SEP	KOSMOS 2263	22802	1993-59A	ZENIT-2	BAIKONUR	849	854	71.00	101.96	ELINT	TSELINA 2 CLASS
17.03 SEP	KOSMOS 2264	22808	1993-60A	TSYKLON-2	BAIKONUR	402	418	65.02	92.77	EORSAT	NEW ORBITAL PLANE; PHASED WITH KOSMOS 2258, 2244, AND 2238
30.71 SEP	RADUGA 30	22836	1993-62A	PROTON-K (4)	BAIKONUR	35761	35808	1.48	1435.99	COMMUNICATIONS	STATIONED AT 85 E
11.90 OCT	PROGRESS M-20	22867	1993-64A	SOYUZ-U	BAIKONUR	388	397	51.62	92.41	MIR RESUPPLY	DOCKED 13 OCT; UNDOCKED 21 NOV
26.54 OCT	KOSMOS 2265	22875	1993-67A	KOSMOS-3M	PLESETSK	291	1573	82.94	103.68	MINOR MILITARY	RADAR CALIBRATION SPHERE
28.64 OCT	GORIZONT 28	22880	1993-69A	PROTON-K (4)	BAIKONUR	35765	35802	1.47	1435.94	COMMUNICATIONS	STATIONED AT 90 E

TABLE 8.1 CIS LAUNCH HISTORY, 1993

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
2.51 NOV	KOSMOS 2266	22888	1993-70A	KOSMOS-3M	PLESETSK	950	1019	82.95	104.79	NAVIGATION	REPLACED KOSMOS 2135/2195
5.35 NOV	KOSMOS 2267	22904	1993-71A	SOYUZ-U	BAIKONUR	240	304	70.39	89.95	PHOTO RECON	5TH GENERATION; RETURNED 28 DEC 94
18.58 NOV	GORIZONT 29	22907	1993-72A	PROTON-K (4)	BAIKONUR	35758	35813	1.46	1436.04	COMMUNICATIONS	STATIONED AT 190 E; FOR RIMSAT CORP.
22.86 DEC	MOLNIYA 1-87	22949	1993-79A	MOLNIYA-M	PLESETSK	470	39884	62.91	717.77	COMMUNICATIONS	REPLACED MOL 1-77; ON STATION 24 MAR 94

TABLE 8.2 CIS LAUNCH HISTORY, 1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
8.42 JAN	SOYUZ TM-18	22957	1994-01A	SOYUZ-U2	BAIKONUR	385	392	51.82	92.33	MANNED	DOCKED AT MIR 10 JAN; UNDOCKED 9 JUL
20.41 JAN	GALS 1	22963	1994-02A	PROTON-K (4)	BAIKONUR	35781	35783	0.22	1435.85	COMMUNICATIONS	STATIONED AT 44 E; MOVED TO 71 E MAY-JUN
25.02 JAN	METEOR 3-6 TUBSAT B	22969 22970	1994-03A 1994-03B	TSYKLON-3	PLESETSK	1187 1185	1208 1209	82.56 82.56	109.36 109.36	METEOROLOGY TECHNOLOGY	CARRIED FRENCH SENSOR COMMERCIAL PIGGY-BACK GERMAN PAYLOAD
28.09 JAN	PROGRESS M-21	22975	1994-05A	SOYUZ-U2	BAIKONUR	385	391	51.82	92.32	MIR RESUPPLY	DOCKED 30 JAN; UNDOCKED 23 MAR
5.37 FEB	RADUGA 1-3	22981	1994-08A	PROTON-K (4)	BAIKONUR	35769	35794	1.50	1435.82	COMMUNICATIONS	STATIONED AT 49 E
12.37 FEB	KOSMOS 2268 KOSMOS 2269 KOSMOS 2270 KOSMOS 2271 KOSMOS 2272 KOSMOS 2273	22999 23000 23001 23002 23003 23004	1994-11A 1994-11B 1994-11C 1994-11D 1994-11E 1994-11F	TSYKLON-3	PLESETSK	1412 1410 1405 1402 1395 1407	1426 1421 1419 1417 1417 1417	82.58 82.57 82.57 82.57 82.57 82.57	114.20 114.13 114.05 113.99 113.91 114.05	COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS COMMUNICATIONS	COPLANAR WITH KOMOS 2245-2250
18.33 FEB	RADUGA 31	23010	1994-12A	PROTON-K (4)	BAIKONUR	35737	35826	1.47	1435.84	COMMUNICATIONS	STATIONED AT 45 E
2.14 MAR	KORONAS-1	23019	1994-14A	TSYKLON-3	PLESETSK	487	528	82.49	94.78	SCIENTIFIC	SOLAR OBSERVATORY; FIRST FLIGHT OF UKRAINIAN AUOS-SM SPACECRAFT BUS
17.69 MAR	KOSMOS 2274	23033	1994-18A	SOYUZ-U	PLESETSK	163	350	67.13	89.84	PHOTO RECON	4TH GENERATION; RETURNED 21 MAY
22.20 MAR	PROGRESS M-22	23035	1994-19A	SOYUZ-U	BAIKONUR	382	403	51.65	92.41	MIR RESUPPLY	DOCKED 24 MAR; UNDOCKED 23 MAY
11.33 APR	KOSMOS 2275 KOSMOS 2276 KOSMOS 2277	23043 23044 23045	1994-21A 1994-21B 1994-21C	PROTON-K (4)	BAIKONUR	19117 19060 19111	19143 19200 19146	64.81 64.80 64.81	675.73 675.73 675.68	NAVIGATION NAVIGATION NAVIGATION	REPLACED KOSMOS 2079 FILLED VACANT 8TH ORBITAL PLANE POSITION REPLACED KOSMOS 1972 IN AUG
23.35 APR	KOSMOS 2278	23087	1994-23A	ZENIT-2	BAIKONUR	849	855	71.01	101.97	ELINT	TSELINA 2 CLASS
26.10 APR	KOSMOS 2279	23092	1994-24A	KOSMOS-3M	PLESETSK	957	1007	82.95	104.73	NAVIGATION	REPLACED KOSMOS 2180
28.72 APR	KOSMOS 2280	23095	1994-25A	SOYUZ-U	BAIKONUR	242	304	70.38	89.98	PHOTO RECON	5TH GENERATION; RETURNED 10 MAR 1995
20.08 MAY	GORIZONT 30	23108	1994-30A	PROTON-K (4)	BAIKONUR	35788	35793	1.28	1436.28	COMMUNICATIONS	STATIONED AT 142.5 E; FOR RIMSAT CORP.

TABLE 8.2 CIS LAUNCH HISTORY, 1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
22.19 MAY	PROGRESS M23	23114	1994-31A	SOYUZ-U	BAIKONUR	398	400	51.65	92.53	MIR RESUPPLY	DOCKED 24 MAY; UNDOCKED 2 JUL
25.43 MAY	KOSMOS ----	NONE	NONE	TSYKLON-3	PLESETSK	---	---	----	----	ELINT	FAILED TO REACH ORBIT; 2ND AND 3RD STAGE SEPARATION MALFUNCTION; POSSIBLE REPLACEMENT FOR KOSMOS 1975
7.31 JUN	KOSMOS 2281	23119	1994-32A	SOYUZ-U	PLESETSK	237	296	82.58	89.84	PHOTO RECON	3RD GENERATION; EARTH RESOURCES; RESURS-T TYPE; RETURNED 29 JUN
14.67 JUN	PHOTON 6	23122	1994-33A	SOYUZ-U	PLESETSK	221	364	62.81	90.36	MATERIALS SCIENCE	RETURNED 2 JUL; AKA PHOTON 9
1.52 JUL	SOYUZ TM-19	23139	1994-36A	SOYUZ-U2	BAIKONUR	396	400	51.65	92.52	MANNED	DOCKED AT MIR 3 JUL; UNDOCKED 4 NOV
6.99+ JUL	KOSMOS 2282	23168	1994-38A	PROTON-K (4)	BAIKONUR	35755	35813	2.29	1435.96	EARLY WARNING	STATIONED AT 336 E
14.22 JUL	NADEZHDA 4	23179	1994-41A	KOSMOS-3M	PLESETSK	954	1005	82.95	104.68	NAVIGATION	REPLACED NADEZHDA 2; COSPAS EQUIPPED
20.73 JUL	KOSMOS 2283	23182	1994-42A	SOYUZ-U	PLESETSK	169	330	67.11	89.50	PHOTO RECON	4TH GENERATION; RETURNED 29 SEP
29.40 JUL	KOSMOS 2284	23187	1994-44A	SOYUZ-U	BAIKONUR	214	277	70.38	89.41	PHOTO RECON	4TH GENERATION; TOPOGRAPHIC MAPPER; RETURNED 11 SEP
2.83 AUG	KOSMOS 2285	23189	1994-45A	KOSMOS-3M	PLESETSK	974	1013	74.03	104.98	UNKNOWN	NEW MILITARY MISSION
5.05 AUG	KOSMOS 2286	23194	1994-48A	MOLNIYA-M	PLESETSK	568	39770	62.90	717.45	EARLY WARNING	REPLACED KOSMOS 2196; ON STATION 8 AUG
11.64 AUG	KOSMOS 2287 KOSMOS 2288 KOSMOS 2289	23203 23204 23205	1994-50A 1994-50B 1994-50C	PROTON-K (4)	BAIKONUR	19112 19092 19121	19147 19168 19138	64.84 64.84 64.84	675.72 675.73 675.73	NAVIGATION NAVIGATION NAVIGATION	NEW ORBITAL PLANE
23.60 AUG	MOLNIYA 3-46	23211	1994-51A	MOLNIYA-M	PLESETSK	604	39757	62.82	717.92	COMMUNICATIONS	REPLACED MOL 3-40; ON STATION 1 SEP
25.60 AUG	PROGRESS M24	23215	1994-52A	SOYUZ-U	BAIKONUR	395	398	51.65	92.49	MIR RESUPPLY	FAILED TO DOCK ON 27 AND 30 AUG; DOCKED 2 SEP; UNDOCKED 4 OCT
26.50 AUG	KOSMOS 2290	23218	1994-53A	ZENIT-2	BAIKONUR	212	292	64.81	89.55	PHOTO RECON	FIRST OF NEW GENERATION; RETURNED 4 APR 1995



TABLE 8.2 CIS LAUNCH HISTORY, 1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
21.75 SEP	KOSMOS 2291	23267	1994-60A	PROTON-K (4)	BAIKONUR	35761	35813	1.45	1436.11	COMMUNICATIONS	GEYSER CLASS; STATIONED AT 80 E
27.58 SEP	KOSMOS 2292	23278	1994-61A	KOSMOS-3M	PLESETSK	400	1954	82.99	108.93	MINOR MILITARY	RADAR CALIBRATION SPHERE
3.95 OCT	SOYUZ TM-20	23288	1994-63A	SOYUZ-U2	BAIKONUR	394	398	51.65	92.47	MANNED	DOCKED 6 OCT; UNDOCKED
11.60 OCT	OKEAN 4	23317	1994-66A	TSYKLOH-3	PLESETSK	632	666	82.54	97.70	OCEANOGRAPHIC	
13.68 OCT	EXPRESS 1	23319	1994-67A	PROTON-K (4)	BAIKONUR	35779	35786	0.17	1435.87	COMMUNICATIONS	FIRST OF NEW SERIES; STATIONED AT 70 E, THEN MOVED TO 346 E IN JAN 95
31.60 OCT	ELEKTRO 1	23327	1994-69A	PROTON-K (4)	BAIKONUR	35773	35795	1.18	1435.95	METEOROLOGY	FIRST OF NEW SERIES; STATIONED AT 76 E
2.04 NOV	KOSMOS 2293	23336	1994-72A	TSYKLOH-2	BAIKONUR	403	417	65.03	92.77	EORSAT	COPLANAR WITH KOSMOS 2264
4.25 NOV	RESURS-O-1	23342	1994-74A	ZENIT-2	BAIKONUR	661	663	98.05	97.98	REMOTE SENSING	FIRST RESURS-O LAUNCHED BY ZENIT 2
11.31 NOV	PROGRESS M-25	23348	1994-75A	SOYUZU	BAIKONUR	393	395	51.65	92.43	MIR RESUPPLY	DOCKED 13 NOV; UNDOCKED
20.03 NOV	KOSMOS 2294 KOSMOS 2295 KOSMOS 2296	23396 23397 23398	1994-76A 1994-76B 1994-76C	PROTON-K (4)	BAIKONUR	19051 19099 19124	19209 19161 19136	64.89 64.88 64.87	675.73 675.73 675.73	NAVIGATION NAVIGATION NAVIGATION	REPLACED KOSMOS 2234 REPLACED KOSMOS 2236 REPLACED KOSMOS 2109
24.39 NOV	KOSMOS 2297	23404	1994-77A	ZENIT-2	BAIKONUR	849	854	71.00	101.97	ELINT	TSELINA 2 CLASS
29.12 NOV	GEO-IK 1	23411	1994-78A	TSYKLOH-3	PLESETSK	1480	1527	73.61	116.06	GEODESY	
14.60 DEC	MOLNIYA 1-88	23420	1994-81A	MOLNIYA-M	PLESETSK	441	39910	62.78	717.69	COMMUNICATIONS	REPLACED MOLNIYA 1-82; ON STATION 31 DEC
16.50 DEC	LUCH 1	23426	1994-82A	PROTON-K (4)	BAIKONUR	35755	35811	2.59	1435.92	COMMUNICATIONS	ALT AIR CLASS; POSITIONED AT 95 E
20.22 DEC	KOSMOS 2298	23431	1994-83A	KOSMOS-3M	PLESETSK	786	810	74.03	100.83	COMMUNICATIONS	REPLACED KOSMOS 2150
26.13 DEC	RADIO-HOSTO (RS-15)	23439	1994-85A	ROKOT	BAIKONUR	1884	2161	64.81	127.71	COMMUNICATIONS	MAIDEN FLIGHT OF ROKOT; 3RD STAGE BROKE UP A FEW HOURS AFTER LAUNCH

TABLE 8.2 CIS LAUNCH HISTORY, 1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
26.04 DEC	KOSMOS 2299	23441	1994-86A	TSYKLON-3	PLESETSK	1401	1416	82.57	113.97	COMMUNICATIONS	COPLANAR WITH KOSMOS 2268-2273
	KOSMOS 2300	23442	1994-86B			1409	1416	82.56	114.05		
	KOSMOS 2301	23443	1994-86C			1412	1417	82.57	114.11		
	KOSMOS 2302	23444	1994-86D			1415	1423	82.57	114.20		
	KOSMOS 2303	23445	1994-86E			1415	1429	82.58	114.26		
	KOSMOS 2304	23446	1994-86F			1412	1418	82.57	114.11		
28.48 DEC	RADUGA 32	23448	1994-87A	PROTON-K (4)	BAIKONUR	35784	35792	1.45	1436.17	COMMUNICATIONS	POSITIONED AT 70 E
29.48 DEC	KOSMOS 2305	23453	1994-88A	SOYUZU	BAIKONUR	240	298	64.91	89.89	PHOTO RECON	5TH GENERATION

TABLE 8.3 ESA LAUNCH HISTORY, 1993

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
12.04 MAY	ASTRA 1C ARENE	22653 22654	1993-31A 1993-31B	ARIANE-42L	KOURU	35649 17666	35929 37041	0.02 1.06	1436.22 1027.59	COMMERCIAL COMMERCIAL	LUXEMBOURG PAYLOAD POSITIONED AT 19.2 E FRANCE PAYLOAD
25.01 JUN	GALAXY 4	22694	1993-39A	ARIANE-42P	KOURU	35774	35800	0.01	1436.11	COMMERCIAL	US PAYLOAD
22.96 JUL	HISPASAT 1B INSAT 2B	22723 22724	1993-48A 1993-48B	ARIANE-44L	KOURU	35778 35769	35795 35807	0.02 0.20	1436.08 1436.16	COMMERCIAL COMMERCIAL	SPAIN PAYLOAD POSITIONED AT 329 E INDIA PAYLOAD POSITIONED AT 93.5 E
26.07 SEP	SPOT 3 STELLA KITSAT 2 POSAT 1 HEALTHSAT 2 ITAMSAT EYESAT	22823 22824 22825 22826 22827 22828 22829	1993-61A 1993-61B 1993-61C 1993-61D 1993-61E 1993-61F 1993-61G	ARIANE-40	KOURU	816 798 795 793 793 795 791	818 805 805 806 805 803 806	98.68 98.68 98.68 98.68 98.68 98.68 98.58	101.23 100.90 100.87 100.86 100.85 100.85 100.84	COMMERCIAL COMMERCIAL COMMERCIAL COMMERCIAL COMMERCIAL COMMERCIAL COMMERCIAL	FRANCE PAYLOAD FRANCE PAYLOAD SOUTH KOREA PAYLOAD PORTUGAL PAYLOAD US PAYLOAD ITALY PAYLOAD US PAYLOAD
22.28 OCT	INTELSAT 701	22871	1993-66A	ARIANE-44LP	KOURU	35664	35916	0.07	1436.26	COMMERCIAL	INTELSAT PAYLOAD POSITIONED AT 174 E
20.05 NOV	SOLIDARIDAD 1 METEOSAT 6	22911 22912	1993-73A 1993-73B	ARIANE-44LP	KOURU	35756 35772	35812 35801	0.04 1.28	1435.97 1436.08	COMMERCIAL METEOROLOGY	MEXICO PAYLOAD ESA PAYLOAD POSITIONED AT 350 E
18.06 DEC	DIRECTV 1 THAICOM 1	22930 22931	1993-78A 1993-78B	ARIANE-44L	KOURU	35772 35771	35809 35802	0.07 0.11	1436.30 1436.10	COMMERCIAL COMMERCIAL	US PAYLOAD THAILAND PAYLOAD POSITIONED AT 78.5 E

TABLE 8.4 ESA LAUNCH HISTORY, 1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
24.90 JAN	EUTELSAT 2 F5 TURKSAT 1A	NONE NONE	NONE NONE	ARIANE-44LP	KOUROU	*** ***	*** ***	*** ***	*** ***	COMMERCIAL COMMERCIAL	FAILED TO REACH ORBIT DUE TO 3RD STAGE MALFUNCTION; EUTELSAT AND TURKEY PAYLOADS
17.30 JUN	INTELSAT 702 STRV 1A STRV 1B	23124 23125 23126	1994-34A 1994-34B 1994-34C	ARIANE-44LP	KOUROU	35688 279 279	35877 35836 35894	0.05 7.04 7.04	1435.90 633.56 634.70	COMMERCIAL COMMERCIAL COMMERCIAL	INTELSAT PAYLOAD POSITIONED AT 359 E EXPERIMENTAL UK PAYLOAD EXPERIMENTAL UK PAYLOAD
08.96 JUL	PAS 2 BS-3N	23175 23176	1994-40A 1994-40B	ARIANE-44L	KOUROU	35646 35777	35937 35800	0.05 0.19	1436.35 1436.20	COMMERCIAL COMMERCIAL	US PAYLOAD JAPAN PAYLOAD POSITIONED AT 110 E
10.96 AUG	BRAZILSAT B1 TURKSAT 1B	23199 23200	1994-49A 1994-49B	ARIANE-44LP	KOUROU	35729 35776	35837 35798	0.05 0.03	1435.90 1436.12	COMMERCIAL COMMERCIAL	BRAZIL PAYLOAD TURKEY PAYLOAD POSITIONED AT 42 E
09.02 SEP	TELSTAR 402	23249	1994-58A	ARIANE-42L	KOUROU	222	35715	6.90	630.11	COMMERCIAL	LAUNCH SUCCESSFUL, BUT US PAYLOAD FAILED AFTER RELEASE FROM 3RD STAGE
08.05 OCT	SOLIDARIDAD 2 THACOM 2	23313 23314	1994-65A 1994-65B	ARIANE-44L	KOUROU	35772 35698	35799 35881	0.22 0.04	1436.05 1436.24	COMMERCIAL COMMERCIAL	MEXICO PAYLOAD THAILAND PAYLOAD POSITIONED AT 78.5 E
01.03 NOV	ASTRA 1D	23331	1994-70A	ARIANE-42P	KOUROU	35742	35831	0.12	1436.10	COMMERCIAL	LUXEMBOURG PAYLOAD POSITIONED AT 19.2 E
01.96 DEC	PANAMSAT 3	NONE	NONE	ARIANE-42P	KOUROU	***	***	***	***	COMMERCIAL	FAILED TO REACH ORBIT DUE TO 3RD STAGE MALFUNCTION; US PAYLOAD

TABLE 8.5 INDIA LAUNCH HISTORY, 1993-1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
1993											
20.22 SEP	IRS-1E	NONE	NONE	PSLV	SRIHARIKOTA	...	...	....	....	REMOTE SENSING	FIRST PSLV LAUNCH ATTEMPT; FAILED TO REACH ORBIT
1994											
04.00 MAY	SROSS C2	23099	1994-27A	ASLV	SRIHARIKOTA	434	921	46.01	98.30	SCIENTIFIC	GEOPHYSICS AND ASTROPHYSICS EXPERIMENTS
15.21 OCT	IRS-P2	23323	1994-68A	PSLV	SRIHARIKOTA	812	821	98.69	101.21	SCIENTIFIC	FIRST INDIAN SUCCESSFUL SUN-SYNCHRONOUS LAUNCH; REMOTE SENSING AND ASTROPHYSICAL PAYLOADS

TABLE 8.6 JAPAN LAUNCH HISTORY, 1993-1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
1993											
20.08 FEB	ASTRO-D (ASUKA)	22521	1993-11A	M-3SII	KAGOSHIMA	538	647	31.10	96.53	SCIENTIFIC	X-RAY ASTROPHYSICAL OBSERVATORY
1994											
03.03 FEB	OFEX VEP	22978 22979	1994-07A 1994-07B	H-II	TANEGASHIMA	449 469	459 36079	30.51 28.54	93.66 642.00	EXPERIMENTAL EXPERIMENTAL	MAIDEN FLIGHT OF THE H-II LAUNCH VEHICLE; OFEX RECOVERED IN PACIFIC AFTER 2 HR 10 MIN
28.33 AUG	ETS-VI	23230	1994-56A	H-II	TANEGASHIMA	7793	38709	13.06	845.95	COMMUNICATIONS	PAYLOAD MALFUNCTION PREVENTED ATTAINMENT OF GEO. SPACECRAFT SYSTEMS TESTED IN NON-NOMINAL ORBIT

TABLE 8.7 PRC LAUNCH HISTORY, 1993-1994

DATE	SATELLITE	SATELLITE NUMBER	INTERNATIONAL DESIGNATOR	LAUNCH VEHICLE	LAUNCH SITE	PERIGEE (KM)	APOGEE (KM)	INCLINATION (DEG)	PERIOD (MIN)	MISSION TYPE	NOTES
1993											
08.33 OCT	FSW-1 5	22859	1993-63A	CZ-2C	JIUQUAN	209	300	56.95	89.60	EARTH OBSERVATION	CAPSULE RECOVERY FAILED ON 16 OCT; ATTITUDE MALFUNCTION SENT CAPSULE INTO HIGHER ORBIT
1994											
08.36 FEB	KF-1 SHI JIAN 4	22996 23009	1994-10A 1994-10B	CZ-3A	XICHANG	208 212	36135 36092	28.56 28.55	638.01 637.25	DEVELOPMENTAL SCIENTIFIC	TEST PAYLOAD FOR MAIDEN FLIGHT OF CZ-3A GEO PHYSICAL SPACECRAFT
03.33 JUL	FSW-2 2	23145	1994-37A	CZ-2D	JIUQUAN	173	343	62.96	89.67	EARTH OBSERVATION	CAPSULE RECOVERED 18 JUL
21.44 JUL	APSTAR 1	23185	1994-43A	CZ-3	XICHANG	35646	35920	0.05	1435.90	COMMERCIAL	HONG KONG PAYLOAD POSITIONED AT 138 E
27.97 AUG	OPTUS B3	23227	1994-55A	CZ-2E	XICHANG	35644	35925	0.78	1435.99	COMMERCIAL	AUSTRALIAN PAYLOAD
29.71 NOV	DFH-3 1	23415	1994-80A	CZ-3A	XICHANG	35181	35993	0.26	1425.91	COMMUNICATIONS	FIRST OF SERIES; FAILED BEFORE ATTAINING GEO POSITION





## **SECTION 9. APPENDICES**

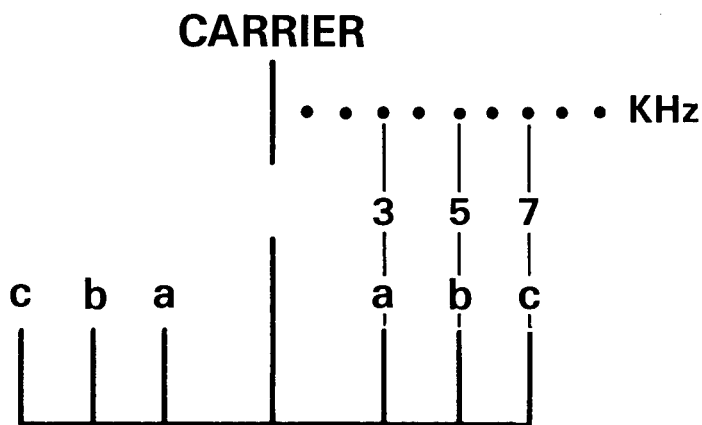
## APPENDIX A1

Frequencies Used by European and Chinese Satellites in 1993 and 1994 as Monitored by the  
Kettering Group

FREQUENCY (MHZ)	DESCRIPTION	USE
29.355	TELEMETRY	RS 10/11 on KOSMOS 1861 RS 15 (RADIO-ROSTO)
121.75	FM VOICE	SOYUZ TM-16, TM-17, TM-18, TM-19
137.30	2 LINES/SEC APT	METEOR 3-3, 3-4, 3-5, 3-6
137.40	4 LINES/SEC APT, <i>Note 1</i>	OKEAN 4
137.40	2 LINES/SEC APT	METEOR 2-21
137.40	TELEMETRY	SROSS-C 2
137.56	CARRIER ONLY	PROSPERO
137.72	TELEMETRY	TEMISAT
137.85	2 LINES/SEC APT	METEOR 2-21, 3-3, 3-5
143.075	TELEMETRY	TUBSAT 1
143.62	FM VOICE	MIR
145.55	AMATEUR RADIO PACKET + VOICE	MIR
145.822	TELEMETRY	INFORMATOR 1
145.825	AMATEUR RADIO	UoSAT 2
145.985	AMATEUR RADIO	RUDAK 2 on INFORMATOR 1 (OSCAR 21/RS 14)
149.91	#2 MILITARY NAVSAT, <i>Note 2</i>	KOSMOS 2184
149.94	#3 MILITARY NAVSAT	KOSMOS 2218
	#6 MILITARY NAVSAT, <i>Note 2</i>	KOSMOS 2180, 2279
149.97	#1 MILITARY NAVSAT	KOSMOS 2135, 2195, 2266
	#4 MILITARY NAVSAT, <i>Note 2</i>	KOSMOS 2173, 2239
150.00	#11 CIVIL NAVSAT	KOSMOS 2181, 2230
	#12 CIVIL NAVSAT	NADEZHDA 3
	#13 CIVIL NAVSAT	KOSMOS 2123
	#14 CIVIL NAVSAT, <i>Note 2</i>	NADEZHDA 2, 4
150.03	#5 MILITARY NAVSAT, <i>Note 2</i>	KOSMOS 2142, 2233
150.30	300 kHz WIDE FM/PCM TELEMETRY WITH 1 SEC FRAME	KOSMOS 2284
150.30	300 KHZ WIDE FM/PCM TELEMETRY WITH 2 SEC FRAME	KOSMOS 2088, 2226, GEO-IK 5
166.0	FM TELEMETRY, <i>Note 3</i>	PROGRESS M-15, M-16, M-17, M-18, M-19, M-21, M-23, M-24, M-25 SOYUZ TM-16, TM-17, TM-18, TM-19, TM-20
179.985	TELEMETRY	CHINA 40
393.675	TELEMETRY	CHINA 40
400.55	SLOW RATE TELEMETRY	FREJA
479.970		CHINA 40
638.0	FM TELEMETRY, <i>Note 3</i>	MIR
922.75		SOYUZ TM-16, TM-18
926.07		PROGRESS M-19, M-21, M-23 PROGRESS M-23

**Note 1:** APT similar to that from the sun-synchronous Meteor 30 but imagery can show visible, microwave sounder, and radar swaths contiguously.

**Note 2:** Fifty bits/second modulation is employed. The data to be transmitted select a low frequency and the resulting sequence amplitude modulates the VHF carrier. The frequency spectrum is shown in figure below. The data to be transmitted select either 3.5 or 7 KHz producing side-bands a, b, c after modulating the carrier. Only the 3 and 5 KHz convey the binary information. Transitional encoding is employed, binary 1 being represented by a change from 3 to 5 KHz or vice versa. Binary 0 produces no frequency shift. The 7 KHz provides time synchronization every second.



**Navigation Satellite Frequency Spectrum**

The numbers marked by # indicate the Soviet orbital plane number assigned to each satellite and transmitted as part of its telemetry. Planes #1-6 are spaced 30 degrees apart covering one hemisphere (180 degrees) and #11-14 are spaced 45 degrees apart to cover the remaining hemisphere.

**Note 3:** This telemetry signal consists of an approximately 250 KHz wide FM spectrum with most of the energy concentrated at the edges of the signal bandwidth, indicating a high modulation index. The modulating signal is probably an amplitude-modulated pulse train, PAM. The normal frame length is 10 milliseconds. The normal number of words per frame is 32. The frequency given in the table indicates the center frequency of the FM spectrum. This frequency is determined as the average of the frequencies of the lower and upper peaks of the FM spectrum. These frequencies can be accurately determined by tuning a frequency-synthesized receiver across them.

**APPENDIX A2.**  
Historical Eurasian Satellite Deployment Failures.

**ELDO SATELLITE DEPLOYMENT FAILURES**

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
30 Nov 1968	***	Europa I	Woomera	Failed to reach orbit
03 Jul 1969	***	Europa I	Woomera	Failed to reach orbit
12 Jun 1970	***	Europa I	Woomera	Failed to reach orbit
05 Nov 1971	***	Europa II	Kourou	Failed to reach orbit

ELDO = European Launcher Development Organization

**ESA SATELLITE DEPLOYMENT FAILURES**

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
23 May 1980	***	Araïne 1	Kourou	Failed to reach orbit
10 Sep 1982	***	Ariane 1	Kourou	Failed to reach orbit
12 Sep 1985	***	Ariane 3	Kourou	Failed to reach orbit
31 May 1986	***	Ariane 2	Kourou	Failed to reach orbit
22 Feb 1990	***	Ariane 44L	Kourou	Failed to reach orbit
24 Jan 1994	***	Ariane 44LP	Kourou	Failed to reach orbit
01 Dec 1994	***	Ariane 42P	Kourou	Failed to reach orbit

**FRANCE SATELLITE DEPLOYMENT FAILURES**

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
08 Feb 1967	1967-011	Diamant	Hammaguir	Orbital stage failure
05 Dec 1971	***	Diamant B	Kourou	Failed to reach orbit
21 May 1973	***	Diamant B	Kourou	Failed to reach orbit

## APPENDIX A2.

### Historical Eurasian Satellite Deployment Failures.

#### INDIA SATELLITE DEPLOYMENT FAILURES

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
10 Aug 1979	***	SLV-3	Sriharikota	Failed to reach orbit
31 May 1981	1981-051	SLV-3	Sriharikota	Orbital stage failure
24 Mar 1987	***	ASLV	Sriharikota	Failed to reach orbit
13 Jul 1988	***	ASLV	Sriharikota	Failed to reach orbit
20 May 1992	1992-028	ASLV	Sriharikota	Orbital stage failure
20 Sep 1993	***	PSLV	Sriharikota	Failed to reach orbit

#### JAPAN SATELLITE DEPLOYMENT FAILURES

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
26 Sep 1966	***	L-4S	Kagoshima	Failed to reach orbit
20 Dec 1966	***	L-4S	Kagoshima	Failed to reach orbit
13 Apr 1967	***	L-4S	Kagoshima	Failed to reach orbit
22 Sep 1969	***	L-4S	Kagoshima	Failed to reach orbit
25 Sep 1970	***	M-4S	Kagoshima	Failed to reach orbit
04 Feb 1976	***	M-3C	Kagoshima	Failed to reach orbit
06 Feb 1979	1979-009	N-I	Tanegashima	Orbital stage failure*
22 Feb 1980	1980-018	N-I	Tanegashima	Orbital stage failure*
15 Jan 1995	***	M-3SII	Kagoshima	Lower stage failure

\* Independent apogee kick stage; not part of basic launch vehicle

**APPENDIX A2.**  
Historical Eurasian Satellite Deployment Failures.

**PRC SATELLITE DEPLOYMENT FAILURES**

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
18 Sep 1973	***	FB-1	Jiuquan	Failed to reach orbit
14 Jul 1974	***	FB-1	Jiuquan	Failed to reach orbit
05 Nov 1974	***	CZ-2	Jiuquan	Failed to reach orbit
10 Nov 1976	***	FB-1	Jiuquan	Failed to reach orbit
27 Jul 1979	***	FB-1	Jiuquan	Failed to reach orbit
29 Jan 1984	1984-008	CZ-3	Xichang	Orbital stage failure
16 Jul 1990	1990-059	CZ-2E	Xichang	Orbital stage failure*
28 Dec 1991	1991-088	CZ-3	Xichang	Orbital stage failure
21 Dec 1992	***	CZ-2E	Xichang	Failed to reach orbit
25 Jan 1995	***	CZ-2E	Xichang	Failed to reach orbit

\* Independent apogee kick stage; not part of basic launch vehicle

**UK SATELLITE DEPLOYMENT FAILURES**

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
02 Sep 1970	***	Black Arrow	Woomera	Failed to reach orbit

## APPENDIX A2.

Historical Eurasian Satellite Deployment Failures.

### USSR / CIS SATELLITE DEPLOYMENT FAILURES

(Compiled with the assistance of Vladimir Agapov)

DATE	INT DESIG	LV FAMILY	LAUNCH SITE	FAILURE TYPE
27 Apr 1958	***	Sputnik	Baikonur	Failed to reach orbit
23 Sep 1958	***	Luna	Baikonur	Failed to reach orbit
12 Oct 1958	***	Luna	Baikonur	Failed to reach orbit
04 Dec 1958	***	Luna	Baikonur	Failed to reach orbit
18 Jul 1959	***	Luna	Baikonur	Failed to reach orbit
15 Apr 1960	***	Luna	Baikonur	Failed to reach orbit
16 Apr 1960	***	Luna	Baikonur	Failed to reach orbit
28 Jul 1960	***	Vostok	Baikonur	Failed to reach orbit
10 Oct 1960	***	Molniya	Baikonur	Failed to reach orbit
14 Oct 1960	***	Molniya	Baikonur	Failed to reach orbit
22 Dec 1960	***	Vostok	Baikonur	Failed to reach orbit
04 Feb 1961	1961-002	Molniya	Baikonur	Orbital stage failure
27 Oct 1961	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
11 Dec 1961	***	Vostok	Baikonur	Failed to reach orbit
21 Dec 1961	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
01 Jun 1962	***	Vostok	Baikonur	Failed to reach orbit
25 Aug 1962	1962-040	Molniya	Baikonur	Orbital stage failure
01 Sep 1962	1962-043	Molniya	Baikonur	Orbital stage failure
12 Sep 1962	1962-045	Molniya	Baikonur	Orbital stage failure
24 Oct 1962	1962-057	Molniya	Baikonur	Orbital stage failure
25 Oct 1962	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
04 Nov 1962	1962-062	Molniya	Baikonur	Orbital stage failure
04 Jan 1963	1963-001	Molniya	Baikonur	Orbital stage failure
03 Feb 1963	***	Molniya	Baikonur	Failed to reach orbit
06 Apr 1963	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
01 Jun 1963	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
10 Jul 1963	***	Vostok	Baikonur	Failed to reach orbit
22 Aug 1963	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
24 Oct 1963	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
11 Nov 1963	1963-044	Molniya	Baikonur	Orbital stage failure
28 Nov 1963	***	Vostok	Baikonur	Failed to reach orbit
19 Feb 1964	***	Molniya	Baikonur	Failed to reach orbit
21 Mar 1964	***	Molniya	Baikonur	Failed to reach orbit
27 Mar 1964	1964-014	Molniya	Baikonur	Orbital stage failure
20 Apr 1964	***	Molniya	Baikonur	Failed to reach orbit
04 Jun 1964	***	Molniya	Baikonur	Failed to reach orbit
23 Oct 1964	***	Kosmos (R-14)	Baiknour	Failed to reach orbit
01 Dec 1964	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit

## APPENDIX A2.

Historical Eurasian Satellite Deployment Failures.

### USSR / CIS SATELLITE DEPLOYMENT FAILURES

(Compiled with the assistance of Vladimir Agapov)

DATE	INT DESIG	LV FAMILY	LAUNCH SITE	FAILURE TYPE
12 Feb 1965	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
20 Feb 1965	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
12 Mar 1965	1965-018	Molniya	Baikonur	Orbital stage failure
10 Apr 1965	***	Molniya	Baikonur	Failed to reach orbit
13 Jul 1965	***	Vostok	Baikonur	Failed to reach orbit
23 Nov 1965	1965-094	Molniya	Baikonur	Orbital stage failure
28 Dec 1965	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
21 Feb 1966	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
01 Mar 1966	1966-017	Molniya	Baikonur	Orbital stage failure
16 Mar 1966	***	Tsyklon	Baikonur	Launch pad explosion
24 Mar 1966	***	Proton	Baikonur	Failed to reach orbit
27 Mar 1966	***	Molniya	Baikonur	Failed to reach orbit
17 May 1966	***	Voskhod	Plesetsk	Failed to reach orbit
24 May 1966	1966-043	Kosmos (R-12)	Kapustin Yar	Shroud failure
16 Sep 1966	***	Vostok	Baikonur	Failed to reach orbit
18 Sep 1966	1966-088	Tsyklon	Baikonur	Orbital stage failure
02 Nov 1966	1966-101	Tsyklon	Baikonur	Orbital stage failure
16 Nov 1966	***	Kosmos (R-14)	Baikonur	Failed to reach orbit
14 Dec 1966	***	Soyuz	Baikonur	Launch Pad Explosion
22 Mar 1967	***	Tsyklon	Baikonur	Failed to reach orbit
08 Apr 1967	1967-032	Proton	Baikonur	Orbital stage failure
17 Jun 1967	1967-063	Molniya	Baikonur	Orbital stage failure
20 Jun 1967	***	Voskhod	Plesetsk	Failed to reach orbit
26 Jun 1967	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
21 Jul 1967	***	Voskhod	Baikonur	Failed to reach orbit
01 Sep 1967	***	Voskhod	Plesetsk	Failed to reach orbit
27 Sep 1967	***	Kosmos (R-14)	Plesetsk	Launch pad explosion
28 Sep 1967	***	Proton	Baikonur	Failed to reach orbit
22 Nov 1967	***	Proton	Baikonur	Failed to reach orbit
16 Jan 1968	1968-003	Voskhod	Plesetsk	Orbital stage failure
07 Feb 1968	***	Molniya	Baikonur	Failed to reach orbit
06 Mar 1968	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
23 Apr 1968	***	Proton	Baikonur	Failed to reach orbit
04 Jun 1968	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
15 Jun 1968	***	Kosmos (R-14)	Baikonur	Failed to reach orbit
20 Jan 1969	***	Proton	Baikonur	Failed to reach orbit
25 Jan 1969	***	Tsyklon	Baikonur	Failed to reach orbit
01 Feb 1969	***	Vostok	Plesetsk	Failed to reach orbit
19 Feb 1969	***	Proton	Baikonur	Failed to reach orbit
21 Feb 1969	***	N-1	Baikonur	Failed to reach orbit
27 Mar 1969	***	Proton	Baikonur	Failed to reach orbit



## APPENDIX A2.

Historical Eurasian Satellite Deployment Failures.

### USSR / CIS SATELLITE DEPLOYMENT FAILURES

(Compiled with the assistance of Vladimir Agapov)

DATE	INT DESIG	LAUNCH VEHICLE	LAUNCH SITE	FAILURE TYPE
02 Apr 1969	***	Proton	Baikonur	Failed to reach orbit
14 Jun 1969	***	Proton	Baikonur	Failed to reach orbit
03 Jul 1969	***	N-1	Baikonur	Launch pad explosion
23 Jul 1969	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
23 Sep 1969	1969-080	Proton	Baikonur	Orbital stage failure
22 Oct 1969	1969-092	Proton	Baikonur	Orbital stage failure
28 Nov 1969	***	Proton	Baikonur	Failed to reach orbit
27 Dec 1969	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
30 Jan 1970	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
06 Feb 1970	***	Proton	Baikonur	Failed to reach orbit
22 May 1970	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
27 Jun 1970	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
21 Jul 1970	***	Voskhod	Plesetsk	Failed to reach orbit
22 Aug 1970	1970-065	Molniya	Baikonur	Orbital stage failure
23 Dec 1970	***	Kosmos (R-14)	Plesetsk	Launch pad explosion
05 Mar 1971	***	Voskhod	Plesetsk	Failed to reach orbit
05 Mar 1971	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
10 May 1971	1971-042	Proton	Baikonur	Orbital stage failure
25 Jun 1971	***	Voskhod	Plesetsk	Failed to reach orbit
27 Jun 1971	***	N-1	Baikonur	Failed to reach orbit
22 Jul 1971	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
03 Aug 1971	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
19 Aug 1971	***	Voskhod	Baikonur	Failed to reach orbit
24 Nov 1971	***	Kosmos (R-12)	Kapustin Yar	Failed to reach orbit
03 Dec 1971	***	Voskhod	Plesetsk	Failed to reach orbit
31 Mar 1972	1972-023	Molniya	Baikonur	Orbital stage failure
25 Apr 1972	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
29 Jul 1972	***	Proton	Baikonur	Failed to reach orbit
02 Sep 1972	***	Voskhod	Plesetsk	Failed to reach orbit
17 Oct 1972	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
23 Nov 1972	***	N-1	Baikonur	Failed to reach orbit
25 Apr 1973	***	Tsyklon	Baikonur	Failed to reach orbit
25 May 1973	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
26 Jun 1973	***	Kosmos (R-14)	Plesetsk	Launch pad explosion
04 Jul 1973	***	Voskhod	Plesetsk	Failed to reach orbit
12 Apr 1974	***	Voskhod	Baikonur	Failed to reach orbit
23 May 1974	***	Soyuz	Plesetsk	Failed to reach orbit
11 Jul 1974	***	Kosmos (R-12)	Plesetsk	Failed to reach orbit
30 Aug 1974	***	Voskhod	Plesetsk	Failed to reach orbit

## APPENDIX A2.

Historical Eurasian Satellite Deployment Failures.

### USSR / CIS SATELLITE DEPLOYMENT FAILURES

(Compiled with the assistance of Vladimir Agapov)

DATE	INT DESIG	LV FAMILY	LAUNCH SITE	FAILURE TYPE
05 Apr 1975	***	Soyuz	Baikonur	Failed to reach orbit
03 Jun 1975	***	Kosmos (R-14)	Kapustin Yar	Failed to reach orbit
16 Oct 1975	***	Proton	Baikonur	Failed to reach orbit
19 Dec 1975	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
01 Jul 1976	1976-062	Molniya	Plesetsk	Orbital stage failure
01 Sep 1976	1976-088	Molniya	Plesetsk	Orbital stage failure
04 Oct 1976	***	Soyuz	Plesetsk	Failed to reach orbit
22 Feb 1977	***	Soyuz	Baikonur	Failed to reach orbit
05 Aug 1977	***	Proton	Baikonur	Failed to reach orbit
10 Aug 1977	***	Soyuz	Baikonur	Failed to reach orbit
29 Nov 1977	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
27 May 1978	***	Proton	Baikonur	Failed to reach orbit
17 Aug 1978	***	Proton	Baikonur	Failed to reach orbit
17 Oct 1978	***	Proton	Baikonur	Failed to reach orbit
19 Dec 1978	1978-118	Proton	Baikonur	Orbital stage failure
20 Dec 1978	1978-119	Kosmos (R-14)	Plesetsk	Orbital stage failure
16 Feb 1979	***	Soyuz	Plesetsk	Failed to reach orbit
12 Oct 1979	***	Soyuz	Plesetsk	Failed to reach orbit
12 Feb 1980	1980-013	Molniya	Plesetsk	Orbital stage failure
18 Mar 1980	***	Vostok	Plesetsk	Launch pad explosion
18 Apr 1980	1980-031	Molniya	Plesetsk	Orbital stage failure
23 Jan 1981	***	Tsyklon	Plesetsk	Failed to reach orbit
28 Mar 1981	***	Soyuz	Baikonur	Failed to reach orbit
11 Sep 1981	1981-088	Molniya	Plesetsk	Orbital stage failure
04 Mar 1982	***	Kosmos (R-14)	Kapustin Yar	Failed to reach orbit
15 May 1982	***	Soyuz	Plesetsk	Failed to reach orbit
12 Jun 1982	***	Soyuz	Baikonur	Failed to reach orbit
18 Jun 1982	1982-061	Kosmos (R-14)	Plesetsk	Orbital stage failure
23 Jul 1982	***	Proton	Baikonur	Failed to reach orbit
30 Aug 1982	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
24 Nov 1982	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
08 Dec 1982	1982-115	Molniya	Baikonur	Orbital stage failure
24 Dec 1982	***	Proton	Baikonur	Failed to reach orbit
25 Jan 1983	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
26 Sep 1983	***	Soyuz	Baikonur	Launch pad explosion
27 Nov 1984	1984-120	Tsyklon	Plesetsk	Orbital stage failure

## APPENDIX A2.

Historical Eurasian Satellite Deployment Failures.

### USSR / CIS SATELLITE DEPLOYMENT FAILURES

(Compiled with the assistance of Vladimir Agapov)

DATE	INT DESIG	LV FAMILY	LAUNCH SITE	FAILURE TYPE
13 Apr 1985	***	Zenit	Baikonur	Failed to reach orbit
21 Jun 1985	1985-053	Zenit	Baikonur	Failed to reach orbit
23 Oct 1985	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
28 Dec 1985	1985-121	Zenit	Baikonur	Orbital stage failure
26 Mar 1986	***	Soyuz	Baikonur	Failed to reach orbit
03 Oct 1986	1986-075	Molniya	Plesetsk	Orbital stage failure
15 Oct 1986	***	Tsyklon	Plesetsk	Failed to reach orbit
29 Nov 1986	***	Proton	Baikonur	Failed to reach orbit
30 Jan 1987	1987-010	Proton	Baikonur	Orbital stage failure
24 Apr 1987	1987-036	Proton	Baikonur	Orbital stage failure
15 May 1987	***	Energiya	Baikonur	Failed to reach orbit
18 Jun 1987	***	Soyuz	Plesetsk	Failed to reach orbit
18 Jan 1988	***	Proton	Baikonur	Failed to reach orbit
17 Feb 1988	1988-009	Proton	Baikonur	Orbital stage failure
09 Jul 1988	***	Soyuz	Baikonur	Failed to reach orbit
27 Jul 1988	***	Soyuz	Plesetsk	Failed to reach orbit
11 Nov 1988	***	Soyuz	Baikonur	Failed to reach orbit
09 Jun 1989	***	Tsyklon	Plesetsk	Failed to reach orbit
03 Apr 1990	***	Soyuz	Plesetsk	Failed to reach orbit
21 Jun 1990	1990-055	Molniya	Plesetsk	Orbital stage failure
03 Jul 1990	***	Soyuz	Plesetsk	Failed to reach orbit
09 Aug 1990	***	Proton	Baikonur	Failed to reach orbit
04 Oct 1990	***	Zenit	Baikonur	Launch pad explosion
25 Jun 1991	***	Kosmos (R-14)	Plesetsk	Failed to reach orbit
30 Aug 1991	***	Zenit	Baikonur	Failed to reach orbit
05 Feb 1992	***	Zenit	Baikonur	Failed to reach orbit
27 Apr 1993	1993-028	Soyuz	Baikonur	Orbital stage failure
27 May 1993	***	Proton	Baikonur	Failed to reach orbit
25 May 1994	***	Tsyklon	Plesetsk	Failed to reach orbit

Launch pad explosion: During final preparation through first few seconds of flight

Failed to reach orbit: Due to launch vehicle or payload malfunction

Orbital stage failure: Did not reach operational orbit

# APPENDIX A3. EUROPEAN AND ASIAN ASTRONAUTS/COSMONAUTS, 1961-1994

<u>Birth Place*</u>	<u>Name</u>	<u>Profession</u>	<u>Year of Selection</u>	<u>Year of First Flight</u>	<u>Missions</u>	<u>Status</u>	<u>Total Days in Space</u>
Afghanistan	Mohmand, A. A.	AF Pilot	1988	1988	Soyuz TM-6	Retired	9
Austria	Viehboeck, F.	Engineer	1989	1991	Soyuz TM-13	Retired	8
Azerbaijan	Manarov, M. K.	Engineer	1978	1987	Soyuz TM-4, TM-11	Retired	541
Belarus	Klimuk, P. I. Kovalyonok, V. V.	AF Pilot AF Pilot	1965 1967	1973 1977	Soyuz 13, 18, 30 Soyuz 25, 29, T-4	Retired Retired	63 216
Belgium	Frimount, D.	Engineer	1984	1992	STS 45	Retired	9
Bulgaria	Alexandrov, A. P. Ivanov, G. I.	AF Pilot AF Pilot	1978 1978	1988 1979	Soyuz TM-5 Soyuz 33	Retired Retired	10 2
Czech Republic	Remek, V.	AF Pilot	1976	1978	Soyuz 28	Retired	8
France	Baudry, P. P. R. Chretien, J.-L. J. M. Clervoy, J.-F. (ESA) Haignere, J.-P. Tognini, M.	AF Pilot AF Pilot Engineer AF Pilot AF Pilot	1980 1980 1985 1985 1985	1985 1982 1994 1993 1992	STS 51G Soyuz T-6, TM-7 STS 66 Soyuz TM-17 Soyuz TM-15	Retired Active Active Active Active	7 33 11 21 14
Germany	Flade, K.-D. Furrer, R. Jahn, S. Merbold, U. (ESA) Messerschmid, E. Schlegel, H. W. Walter, U.	AF Pilot Physicist AF Pilot Physicist Physicist Physicist Physicist	1990 1982 1976 1976 1982 1987 1987	1992 1985 1978 1983 1985 1993 1993	Soyuz TM-14 STS 61A Soyuz 31 STS 9, 42, Soyuz TM-20 STS 61A STS 55 STS 55	Inactive Retired Retired Active Retired Inactive Inactive	8 7 8 50 7 10 10
Hungary	Farkas, B.	AF Pilot	1978	1980	Soyuz 36	Retired	8
India	Sharma, R.	AF Pilot	1982	1984	Soyuz T-11	Retired	8
Italy	Malerba, F.	Engineer	1978	1992	STS 46	Retired	8

# APPENDIX A3. EUROPEAN AND ASIAN ASTRONAUTS/COSMONAUTS, 1961-1994

<u>Birth Place*</u>	<u>Name</u>	<u>Profession</u>	<u>Year of Selection</u>	<u>Year of First Flight</u>	<u>Missions</u>	<u>Status</u>	<u>Total Days In Space</u>
Japan	Akiyama, T.	Journalist	1989	1990	Soyuz TM-11	Retired	8
	Mohri, M.	Chemist	1985	1992	STS 47	Active	8
	Naito-Mukai, C.	Doctor	1985	1994	STS 65	Active	15
Kazakhstan	Aubakirov, T. O.	AF/Civ Test Pilot	1991	1991	Soyuz TM-13	Retired	8
	Musabayev, T. A.	Civ/AF Pilot	1991	1994	Soyuz TM-19	Active	126
	Patsayev, V. I.	Engineer	1968	1971	Soyuz 11	Deceased	24
	Shatalov, V. A.	AF Pilot	1963	1969	Soyuz 4, 8, 10	Retired	10
	Viktorenko, A. S.	AF Pilot	1978	1987	Soyuz TM-3, TM-8, TM-14, TM-20	Active	489**
Latvia	Kaleri, A. Y.	Engineer	1984	1992	Soyuz TM-14	Active	146
	Solovyev, A. Y.	AF Pilot	1976	1988	Soyuz TM-5, TM-9, TM-15	Active	378
Mongolia	Gurragcha, Z.	Army Engineer	1978	1981	Soyuz 39	Retired	8
Netherlands	Ockels, W. (ESA)	Physicist	1978	1985	STS 61A	Retired	7
Poland	Hermaszewski, M.	AF Pilot	1976	1978	Soyuz 30	Retired	8
Romania	Prunariu, D. D.	AF Pilot	1978	1981	Soyuz 40	Retired	8
Russian Federation	Afanasyev, V. M.	AF Pilot	1985	1990	Soyuz TM-11, TM-18	Active	357
	Aksenov, V. V.	Engineer	1973	1976	Soyuz 22, T-2	Retired	12
	Alexandrov, A. P.	Engineer	1978	1983	Soyuz T-9, TM-3	Retired	157
	Artyukhin, Y. P.	AF Engineer	1963	1974	Soyuz 14	Retired	16
	Atkov, O. Y.	Doctor	1977/83	1984	Soyuz T-10	Retired	237
	Avdeyev, S. V.	Engineer	1987	1992	Soyuz TM-15	Active	189
	Balandin, A. N.	Engineer	1978	1990	Soyuz TM-9	Inactive	179
	Belyayev, P. I.	AF Pilot	1960	1965	Voskhod 2	Deceased	1
	Berezovoy, A. N.	AF Pilot	1970	1982	Soyuz T-5	Retired	211
	Bykovsky, V. F.	AF Pilot	1960	1963	Vostok 5, Soyuz 22, 31	Retired	21
	Demin, L. S.	AF Engineer	1963	1974	Soyuz 15	Retired	2
	Feoktistov, K. P.	Engineer	1964	1964	Voskhod 1	Retired	1
	Filipchenko, A. P.	AF Pilot	1963	1969	Soyuz 7, 16	Retired	11
	Gagarin, Yu. A.	AF Pilot	1960	1961	Vostok 1	Deceased	<1
	Glazkov, Y. N.	AF Engineer	1965	1977	Soyuz 24	Retired	18
	Gorbatko, V. V.	AF Pilot	1960	1969	Soyuz 7, 24, 37	Retired	31
	Grechko, G. M.	Engineer	1966	1975	Soyuz 17, 26, T-14	Retired	135

# APPENDIX A3. EUROPEAN AND ASIAN ASTRONAUTS/COSMONAUTS, 1961-1994

<u>Birth Place*</u>	<u>Name</u>	<u>Profession</u>	<u>Year of Selection</u>	<u>Year of First Flight</u>	<u>Missions</u>	<u>Status</u>	<u>Total Days in Space</u>
Russian Federation (continued)	Gubarev, A. A.	AF Pilot	1963	1975	Soyuz 17, 28	Retired	37
	Ivanchenkov, A. S.	Engineer	1973	1978	Soyuz 29, T-6	Retired	148
	Khrunov, Y. V.	AF Pilot	1960	1969	Soyuz 5	Retired	2
	Komarov, V. M.	AF Pilot	1960	1964	Voskhod 1, Soyuz 1	Deceased	2
	Kondakova, Y. V.	Engineer	1989	1994	Soyuz TM-20	Active	169**
	Krikalev, S. K.	Engineer	1985	1988	Soyuz TM-7, TM-12, STS 60	Active	472
	Kubasov, V. N.	Engineer	1966	1969	Soyuz 6, 19, 36	Retired	19
	Laveykin, A. I.	Engineer	1978	1987	Soyuz TM-2	Retired	174
	Lazarev, V. G.	AF Pilot/Doctor	1964	1973	Soyuz 12	Deceased	2
	Lebedev, V. V.	Engineer	1972	1973	Soyuz 13, T-5	Retired	219
	Leonov, A. A.	AF Pilot	1960	1965	Voskhod 2, Soyuz 19	Retired	7
	Makarov, O. G.	Engineer	1966	1973	Soyuz 12, 27, T-3	Retired	21
	Malyshev, Y. V.	AF Pilot	1967	1980	Soyuz T-2, T-11	Retired	12
	Manakov, G. M.	AF Pilot	1985	1990	Soyuz TM-10, TM-16	Active	310
	Nikolayev, A. G.	AF Pilot	1960	1962	Vostok 3, Soyuz 9	Retired	22
	Poleshchuk, A. F.	Engineer	1989	1993	Soyuz TM-16	Active	179
	Polyakov, V. V.	Doctor	1972	1988	Soyuz TM-6, TM-18	Active	679**
	Romanenko, Y. V.	AF Pilot	1970	1977	Soyuz 26, 38, TM-2	Retired	431
	Rozhdestvensky, V. I.	AF Engineer	1965	1976	Soyuz 23	Retired	2
	Rukavishnikov, N. N.	Engineer	1967	1971	Soyuz 10, 16, 33	Retired	10
	Ryumin, V. V.	Engineer	1973	1977	Soyuz 25, 32, 35	Retired	362
	Sarafanov, G. V.	AF Pilot	1965	1974	Soyuz 15	Retired	2
	Savinykh, V. P.	Engineer	1978	1981	Soyuz T-4, T-13, TM-5	Retired	253
	Savitskaya, S. Y.	Pilot	1980	1982	Soyuz T-7, T-12	Retired	20
	Serebrov, A. A.	Engineer	1978	1982	Soyuz T-7, T-8, TM-8, TM-17	Active	373
	Sevastyanov, V. I.	Engineer	1967	1970	Soyuz 9, 18	Retired	81
	Solovyev, V. A.	Engineer	1978	1984	Soyuz T-10, T-15	Retired	362
	Strekalov, G. M.	Engineer	1973	1980	Soyuz T-3, T-8, T-11, TM-10	Active	154
	Tereshkova, V. V.	AF Engineer	1962	1963	Vostok 6	Retired	3
	Titov, G. S.	AF Pilot	1960	1962	Vostok 2	Retired	1
	Titov, V. G.	AF Pilot	1976	1983	Soyuz T-8, TM-4	Active	376
	Usachev, Y. V.	Engineer	1989	1994	Soyuz TM-18	Active	182
	Volkov, V. N.	Engineer	1964	1969	Soyuz 7, 11	Deceased	29
	Volynov, B. V.	AF Pilot	1960	1969	Soyuz 5, 21	Retired	52
	Yegorov, B. B.	Doctor	1964	1964	Voskhod 1	Deceased	1
	Yeliseyev, A. S.	Engineer	1964	1969	Soyuz 5, 8, 10	Retired	10
	Zudov, V. D.	AF Pilot	1965	1976	Soyuz 23	Retired	2
Saudi Arabia	Al-saud, S. S.	Civilian/Pilot	1984	1985	STS 51G	Retired	7
Switzerland	Nicollier, C. (ESA)	AF Pilot	1978	1992	STS 46, 61	Active	19

# APPENDIX A3. EUROPEAN AND ASIAN ASTRONAUTS/COSMONAUTS, 1961-1994

<u>Birth Place</u>	<u>Name*</u>	<u>Profession</u>	<u>Year of Selection</u>	<u>Year of First Flight</u>	<u>Missions</u>	<u>Status</u>	<u>Total Days in Space</u>
Syria	Faris, M. A.	AF Pilot	1985	1987	Soyuz TM-3	Retired	8
UK	Sharman, H. P.	Engineer	1989	1991	Soyuz TM-12	Retired	8
Ukraine	Artsebarsky, A. P.	AF Pilot	1985	1991	Soyuz TM-12	Retired	145
	Beregovoy, G. T.	AF Pilot	1964	1968	Soyuz 3	Deceased	4
	Dobrovolsky, G. T.	AF Pilot	1963	1971	Soyuz 11	Deceased	24
	Kizim, L. D.	AF Pilot	1965	1980	Soyuz T-3, T-10, T-15	Retired	375
	Levchenko, A. S.	Civ Test Pilot	1978	1987	Soyuz TM-4	Deceased	8
	Lyakhov, V. A.	AF Pilot	1967	1979	Soyuz 32, T-9, TM-6	Retired	333
	Malenchenko, Y. I.	AF Pilot	1987	1994	Soyuz TM-19	Active	126
	Popov, L. I.	AF Pilot	1970	1980	Soyuz 35, 40, T-7	Retired	201
	Popovich, P. R.	AF Pilot	1960	1962	Vostok 4, Soyuz 14	Retired	19
	Shonin, G. S.	AF Pilot	1960	1969	Soyuz 6	Retired	5
	Tsibilyev, V. V.	AF Pilot	1987	1993	Soyuz TM-17	Active	197
	Vasyutin, V. V.	AF Pilot	1976	1985	Soyuz T-14	Retired	65
	Volk, I. P.	Civ Test Pilot	1978	1984	Soyuz T-12	Active	12
	Volkov, A. A.	AF Pilot	1976	1985	Soyuz T-14, TM-7, TM-13	Active	391
	Zholobov, V. M.	AF Engineer	1963	1976	Soyuz 21	Retired	49
Uzbekistan	Dzhanibekov, V. A.	AF Pilot	1970	1978	Soyuz 27, 39, Soyuz T-6, T-12, T-13	Retired	146
Vietnam	Pham Tuan	AF Pilot	1979	1980	Soyuz 37	Retired	8

\* Birth place may not be synonymous with official nationality

\*\* Soyuz TM-20 mission, with Soyuz TM-18 crew member Polyakov, completed in early 1995





## **SECTION 10. ACKNOWLEDGMENTS AND CREDITS**

## 10. ACKNOWLEDGMENTS AND CREDITS

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Mr. Vladimir Agapov: Appendix A2.

Applied Mechanics Scientific Production Association: Figures 4.36 and 4.45.

Asia Satellite Telecommunications Company: Figures 4.11 and 4.12.

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Centre National d'Etudes Spatiales (CNES): Figure 4.66.

China Great Wall Industry Corporation (CGWIC): Figures 4.24, 4.73, and 4.74.

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